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COVER: Fabulous specimens of crystallized dark-blue azurite and calcite and fibrous green malachite are the legacy of Bisbee, Arizona. (Specimens from the Evan Jones collection/Photos by Bob Jones)

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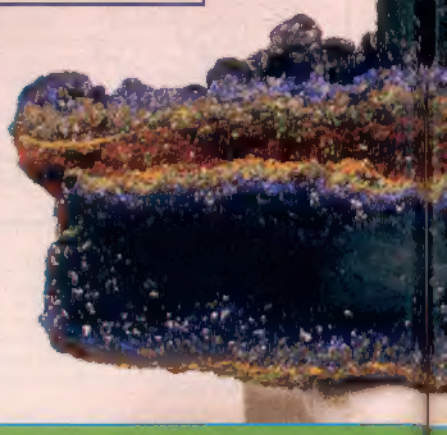
This Bisbee specimen shows a nice combination of calcite and fibrous green malachite. (Evan Jones specimens/Photos by the author)

Crystallized dark blue azurite shows pale blue tips of the same mineral. Inset left: Lovely powder blue botryoidal azurite.



BISBEE UNDE

by Bob Jones

What would Bisbee, Arizona, have been like if copper, silver, gold, and other metals had not been discovered there in such rich amounts? You may be surprised to know that it could still have become famous!

The state of Arizona is world renowned for its geological wonders, with the Grand Canyon leading the way. More recently, the discovery and development of Kartchner Caverns, about 50 miles north of Bisbee as the crow flies, have been touted in *National Geographic* as one of the great cave systems in the world. In fact, Kartchner is ranked among the top 10 most beautiful caves in the world.

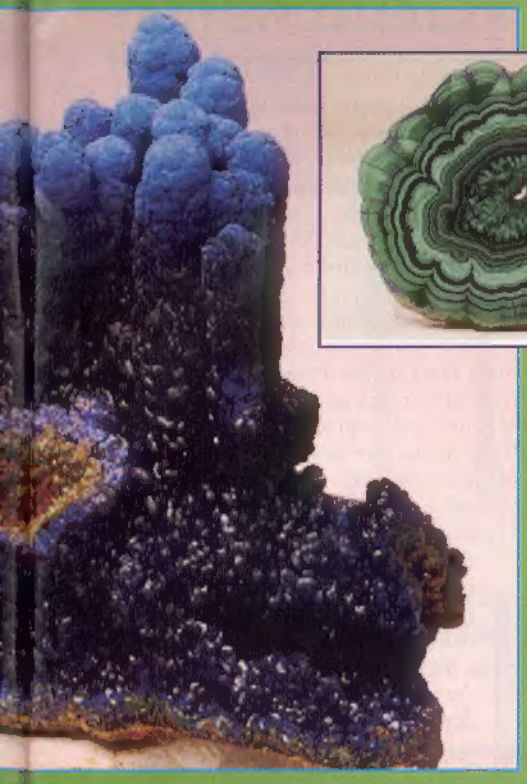
So what, pray tell, does this have to do with Bisbee becoming famous if its rocks had been bereft of copper ores? It so happens that Kartchner's host rock, the Escabrosa limestone series, is also the same limestone that held one of this country's richest copper deposits ever found! So under different circumstances, the Bisbee region without its fantastic copper minerals could have become famous for its limestone caverns, just like Kartchner Caverns.

The sequence that resulted in this rich deposit covers eons of time. Initially, igneous rocks intruded into the country rock, fracturing the rock, including the local limestone. As the igneous rock and the surrounding host rock cooled, they continued to fracture from shrinkage. These fractures became the avenues into which mineral-rich solutions could later ascend. These solutions, as they cooled, began to drop their mineral load in the form of sulfides, mainly copper sulfides.

At the same time, the ever-present action of weathering attacked the limestone and the primary copper minerals. Weathering is not a sometimes event. It is ongoing, so it relentlessly continues to attack not only the limestone, but the copper species. Sulfides break down into oxide minerals and these are carried down through whatever openings are available, only to be re-deposited when conditions are right.

This was the source of Bisbee's azurite, which lined cavities and caverns, created rich malachite stalactites, and tinted the solutions that formed the green calcite cave formations. When these same mineral-bearing solutions hit the water table, which in the desert can be more than 1,000 feet down, they drop their mineral load. Because there is little or no oxygen available at that depth, newly formed secondary sulfides like bornite and chalcocite develop in a more or less rich blanket, a solid layer of maybe 70 percent copper! Originally, these lower layers of sulfides were thought to be primary ores, ores initially deposited and not put there by weathering. But studies at another copper deposit in Bristol, Connecticut, showed that such deposits can be secondarily formed. I've seen a similarly rich zone exposed by mining 2,000 feet underground in Mexico. There it was, a solid wall of copper, zinc and lead sulfides some 10 feet thick and extending hundreds of feet. I must say it was impressive.

So, the Escabrosa limestone of Bisbee was actually assaulted from below by intrusion and by ascending mineral-rich solutions. At the same time, it was assaulted from above by the action of



Gem quality malachite and azurite was a rare find at Bisbee. Inset left: A cross section of a malachite stalactite.

RGROUND Was Copper Its Only Treasure?

weathering. The end results were twofold. First, some amazing and sometimes very colorful limestone formations and caverns were developed, which only the miners and their visitors ever got to see. Second, a huge number of common to very rare mineral species were created that today numbers close to 400 individual chemical compounds at Bisbee.

Since the discovery of silver in the 1870s when a prospector picked up a bit of native metal, Bisbee has produced a fantastic amount and variety of gorgeous minerals. I seriously doubt there is a major museum or university mineral display that lacks at least one choice azurite from Bisbee. Huge plates 2 or more feet across covered with bright dark blue azurites can be seen in such collections.

I find two forms of azurite from Bisbee particularly appealing. One is the sharp, perfectly formed, deep blue, nearly black crystals, very lustrous and perfect. Sometimes these crystals are more than 2 inches across. Others cluster in what are called "roses," taking on a near-spherical shape with crystal terminations protruding.

My second favorite azurite from Bisbee is the delightful almost sky blue, velvety, botryoidal masses consisting of microscopic crystals of very pale blue color. This type of azurite is found in botryoidal layers or thick, long fingers of velvety blue hue. It is undoubtedly the least common of the Bisbee azurites.

Going along with an abundance of azurites from Bisbee are the equally abundant velvet malachite specimens. Some vugs encountered were 2 or more feet across, completely lined with lush, green velvet malachite. Touch it and it is scarred for life it is so soft. But when the specimen is perfect it looks like an undulating putting green! The rarest of the malachites are those that are hairlike inclusions in calcite, making them into brilliant green prisms.

A third superb Bisbee mineral is cuprite, which comes in two forms: textbook, sharp, metallic-looking cubes and needlelike hairs of brilliant red, which have been given the variety name chalcotrichite. Chalcotrichite looks like a red, matted tangle of fiery hair. Sometimes it ends up locked inside sharp calcite crystals, turning them into bright red gems.

While azurite, malachite and cuprite rank as the more common secondary copper species from Bisbee, there are some species that are extremely rare, connellite and paramelaconite for example. Only a few specimens of these were ever recovered and they are the Holy Grail of Bisbee species collectors.

Mining at Bisbee had a very deleterious effect on the caverns and mineral vugs of Bisbee. Most were only seen by miners and then destroyed, leaving behind vast empty stopes and chutes. While all the spectacular caverns and formations underground at Bisbee have been destroyed, we do have the descriptions left by those miners who actually experienced the underground scenery. That is some consolation. And fortunately, we actually have a small but impressive photographic record, thanks to a most unusual event. Some of these caverns, now lost forever, were actually documented on black-and-white film by a local photographer, not just any old photographer but a woman.

continued on next page

Bisbee Underground *from page 13*

In the early days of the 20th century, about 100 years ago, a photographer, the mother of a friend of mine, managed to haul her camera, film, and flash powder underground at Bisbee and document some of the fantastic sights. For a photographer to be able to document the Bisbee underground was rare enough. But for a woman to do it was unheard of in those days. After all, it was considered very bad luck to allow any woman to enter a mine. Still, she went underground and captured images of miners, some working and some relaxing in the fairyland of formations they encountered in the limestone. My only regret—and hers, too, I imagine—is that color film had not yet been created in 1910. Still, she did a marvelous job of capturing on film delicate stalactites, thick fluted columns, small underground lakes, and a host of beautiful limestone formations. While our doughty photographer could not capture the colorful beauty she saw, she did catch on film the stark and delicate beauty of underground Bisbee so well that her portrayal of the handiwork of nature leaves the viewer virtually speechless.

As you look at the black-and-white cave pictures, just imagine, if you will, walking into a limestone cavern whose stalactites are green, or a delicate shade of that verdant color. Imagine walls lined with sparkly, deep-blue azurite crystals. That's what early Bisbee miners actually found as they penetrated to depth at Bisbee.

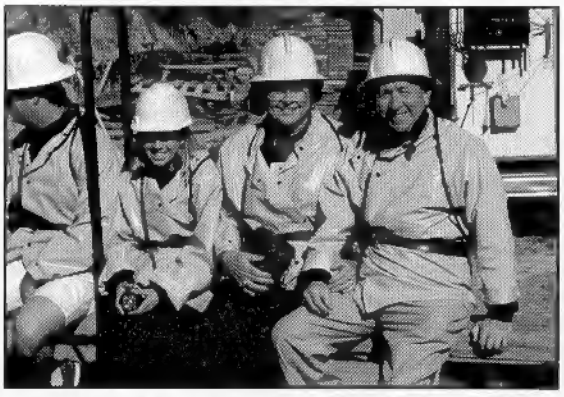
One such cavern opened in those early days was so brilliantly decorated with secondary copper species that the miners called it "The Jewel Box." Imagine the excitement of chiseling specimen after specimen off the walls of such a huge cavern. In one sense it was a huge geode filled with azurite treasures.

The only evidence in hand that we have of such occurrences are the thousands of azurite crystal groups, some 2 or more feet across, that have survived. And we have those few rare slices of malachite, some with alternating azurite and malachite banding, that have been saved and cut in cross section to show the original stalactite growth pattern. That's what miners sometimes saw in the natural state in those early days of mining in Bisbee. And they are the surviving evidence of what was an amazing copper deposit, now long since gone.

Understand that the miner's goal was not the preservation of natural beauty, and more's the pity. His goal was to extract every single ounce of copper possible from the vast reserves that put Bisbee on the map as one of the world's great copper deposits. The goal was profit. But imagine the money that could have been made if they had preserved just one huge azurite-lined cavern, just one pocket of rich green stalactites and stalagmites. People from all over the world would still be trekking to Bisbee to see such a phenomenon and they would pay dearly for the experience.

Now don't get the idea that the mine owners simply gouged and blasted these stunningly beautiful caverns with no thought to preservation. Indeed not! They knew a good thing when it was handed to them. In one such cavern they actually installed a wooden floor so that when potential investors came to visit they could be feted with a luncheon served underground, surrounded by rich blue azurite-coated walls! I suspect the company had little trouble mining cash out of those investors' pockets!

Right to left, senior editor Bob Jones, his wife, Carol, and granddaughter Kiera O'Brien take the Copper Queen Mine tour at Bisbee, Arizona.



Once the azurite had been mined out, that same cavern was used to promote public relations within the city. The company allowed the local high school to hold its graduation dances there. Try doing that today and you'd end up with lawsuits from kids' parents because their little darlings got a chill in that stygian dance hall!

Some years ago I went underground at Bisbee, but found nothing of beauty remaining. I'm sure there are still undiscovered caverns that are reasonably preserved, but what I found were huge, open stopes where mining had removed virtually all rock that tested high enough in copper. Some stopes at Bisbee are so huge that when you shine a five-cell flashlight toward the opposite wall the light is absorbed by the darkness and the opposite wall remains unseen! It has been said that there are some 2,000 miles of tunnels in the Bisbee mines. Remember, tunnels are usually dug only to get to the ore, not to extract it.

Like so many metal-rich limestone deposits, Bisbee has benefited from the ore-bearing solutions coming up from the depths. In later years, when the richest oxide ores played out, the Bisbee mining companies had already turned their attention to the nearby copper porphyry deposits, which sustained the production figures and led to the opening of the huge Lavendar Pit, a pit that exposed so many of the underground workings.

What distinguishes Bisbee from so many other copper deposits is the great variety of mineral species it has produced, species that approach 400 in number. Some are so rare as to exist only as a single specimen. Others, like azurite, are scattered the world over and displayed in a host of museums and private collections. Together, both the abundant and rare have made Bisbee one of the great mineral species deposits of the world.

In the earliest days of mining it was the rich oxide ores that sustained the deposit financially. There were no railroads to the area in the earliest days, nor was there a smelter. So only the richest ores could be hauled by wagon overland to the Gulf of California, where it was transshipped by sailing vessel to Swansea, Wales, then the largest smelting complex in the world. It didn't take long for a railroad to reach Bisbee and for a smelter to be constructed. Scientists soon converged on the mining camp and took away fine specimens of azurite, cuprite and malachite, and such rare species as were found during mining operations. One of the earliest American mineral suppliers, A.E. Foote of Philadelphia, spent time in Bisbee and sent specimens across the country to Eastern museums. The mining camp quickly gained fame as a major copper deposit and a ready source of fine specimens.

As modern science developed the ability to identify the rare and unusual, the ores of Bisbee began to yield more and more species. Along with the common species, research proved such things as anthonyite, bisbeeite, claringbullite, connellite, embolite, graemite, kornelite, rhomboclase, spangolite, szomolnokite and voltaite. You'll probably never see a specimen of any of these minerals, but each adds to the science and reputation of this vast and unusual deposit. There are only a few mineral deposits—Franklin/Sterling Hill, New Jersey, Langban, Sweden, and Tsumeb, Namibia—that have come close to producing as many mineral species as has Bisbee. Much of the credit for such finds should go to Sid Williams, who worked diligently on Bisbee minerals for years, ferreting out the new and rare. Another fellow involved

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Bisbee Underground *from page 14*

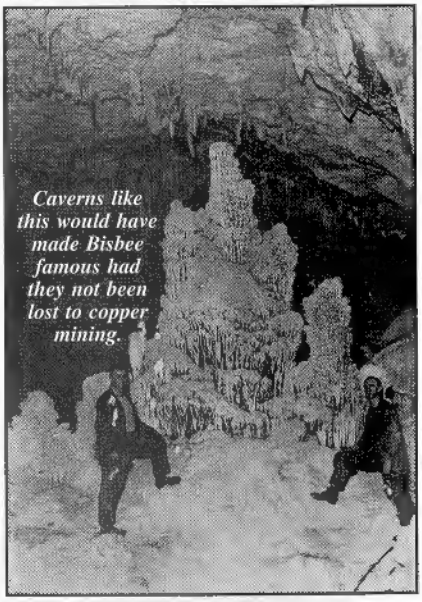
there was Dick Graeme who, as mine superintendent, kept a practiced eye out for anything odd and unusual, and passed along his finds to Williams for checking. Sid, along with John Anthony and Dick Bideaux, authored the first really extensive text on the mineralogy of the state of Arizona.

One of the early mining practices revealed by the photographer who documented Bisbee's caverns is the use of mules underground. Today we use electric equipment to move huge loads of rock from the mining "face" to the ore chute and on to the crusher. But in the earliest days of mining it was human power that got the ore to grass. It didn't take miners long to realize they could use small animals to do the work. The animals had to be small because miners did not remove any more rock than necessary to get to the ore vein, so tunnels were narrow and low. In the emerald mines of Colombia, where human power is often still used, I walked about 1,500 meters underground to get to the gem-bearing vein. The tunnel was no more than 4 feet high and not wide enough for two people to walk side by side, so the armed guard with me walked behind me and we both walked in a half crouch. Try doing that for nearly a mile. You will discover leg and back muscles you never knew existed!

Be that as it may, the miners at Bisbee, as at other mines, soon made plans to take mules into the bowels of the Earth. Using a huge canvas sling, the poor animals, in some cases small horses, were lowered into the mines to the working level. There they would stay, hauling ore cars, until they died, never to see the light of day again. Stalls were constructed, hay was lowered into the mine, and the animals' droppings were hauled out. You can be sure that the newest rookie miner assigned to the underground learned two things: how to shovel out the mule stalls and how to dispose of the contents of the "honey" wagon that was available for the men in their working area.

Mentioning the honey wagon reminds me of one of the classic mining stories. Once candles were superseded by the carbide lamp, miners had a source of light that could last for several hours. The carbide produced a flame that was smokeless and quite bright. A lot of my underground collecting was done by carbide lamp.

The carbide produced flammable acetylene gas from a reaction between water and calcium carbide. There was always a steady supply of water in a mine, either from overhead dripping or from the miner himself. His extra carbide was kept in a fairly watertight metal can (a handy tobacco tin would do). At some point during his shift, the miner's carbide lamp would burn low. Shaking it would usually brighten the flame, but this was a warning that it was time to reload the lamp.



Caverns like this would have made Bisbee famous had they not been lost to copper mining.

It was not unusual for a miner to recharge his carbide lamp while also taking advantage of the nearby honey wagon. After all, it was parked in quiet spot and the miner could take care of two tasks at once. Because this lamp operation had to be done in total darkness, the familiarity of the honey wagon kept the miner from being disoriented in the dark. Usually the miner would dump the residual carbide from his lamp into the honey wagon, since it was well within reach. The lamp would be recharged and ignited again. The problem, if there was one, came if the miner smoked and, having finished his cigarette while relaxing on the honey wagon, dropped the still-lighted cigarette into the depths of his "throne." If conditions were just right, the residual carbide, some of which wasn't quite exhausted, would produce enough acetylene to cause a considerable explosion, thus propelling the unsuspecting miner along the tunnel floor. Needless to say, the contents of the honey wagon might go along with him, making him a pariah for the remainder of his shift!

While some of the stories of mining may be more legendary, sometimes scary, sometimes funny, the descriptions of Bisbee underground are not only accurate, but quite astounding. Proof of this lies in the thousands of gorgeous specimens still to be seen around the world and the few superbly executed black-and-white photos taken underground in Bisbee almost 100 years ago. As you look at those photographs and admire the specimens you see, remember that Bisbee truly was one of the more remarkable ore deposits ever entered by humankind.

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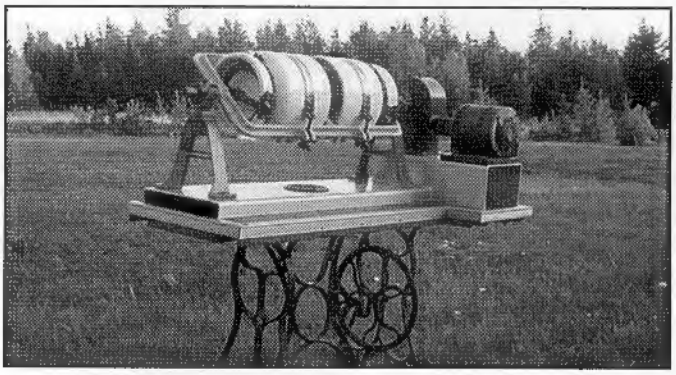
SHOP TALK

by William A. Kappele

Restoring Lapidary Equipment, Part II



This month's photo is another view of Tim Hubley's double jar ball mill/tumbler. If all of our restoration projects turn out this well, we can be proud, indeed. In March, we got started with a discussion of restoring an old machine, and talked about the sheet metal parts like the coolant tank, etc. Let's start this month with the basic castings. Most often, lapidary machines will have these parts made of cast iron. Some may be of aluminum, but by far the most common is cast iron. Fortunately, these parts usually need nothing more than a good cleaning and a nice coat of paint to restore them to their former glory.

There are times, though, when you will find a broken casting. This can be as minor as a broken mounting ear or as serious as a casting broken right in half. Fortunately, cast iron can be brazed or welded successfully in almost every case. The resulting repair may not be cosmetically pleasing, but the function of the machine will not suffer. In some cases, such cast iron repairs will require some machine shop work to realign bearing bosses, but any decent machine shop can handle this at far less cost than that of a new machine. A little cleanup of the welds and a fresh coat of paint, and your casting is ready for a lot more years of service.

Probably the most common parts to need replacing are bearings. There are three basic types of bearings that you are apt to find: ball bearings, roller bearings, and tapered roller bearings. It doesn't really matter which kind you have. If they are grinding and crunching, you will have to replace them. You might get a few more miles out of them with a thorough cleaning and oiling, but if they have enough crud in them to make noise, then obviously the seals are shot and the same thing will just happen again.

The first step is to get the old bearings out of their castings. If they are stuck tight, look up a shop that works on electric motors, alternators and such. There should be someone there with a puller that will get them out. Now the fun begins. There is an absolutely mind boggling number of bearings in the world. If you are lucky, there will be a number on your old bearing that will cross reference with a new one. If, however, your bearing either is blank or is made in Outer Mongolia (or both), you are in for some detective and/or machine shop work. A large hardware store or a local machine shop should have access to bearing dealers. They can measure your old bearing and look up one that will fit your application. In case you have a real oddball size, your castings can usually be bored out to take a bearing with a slightly larger outside diameter.

A fourth type of bearing is called a bushing. They are usually made of a special type of bronze and look like a small piece of tubing. Bushings are used for lower-speed operations or applications like the slides for the vise on a saw. They are readily available, too, but if you can't find the exact size, any machine shop can make them for you.

Finally, shafts that are rusted, pitted or bent can usually be brought back to life. If one is beyond repair, a new one can be made at any machine shop. I've made several references to machine shops, and you probably have dollar signs in your eyes by now, but chances are that you will be able to do most, if not all, of your restoration by yourself.

LEONARDO

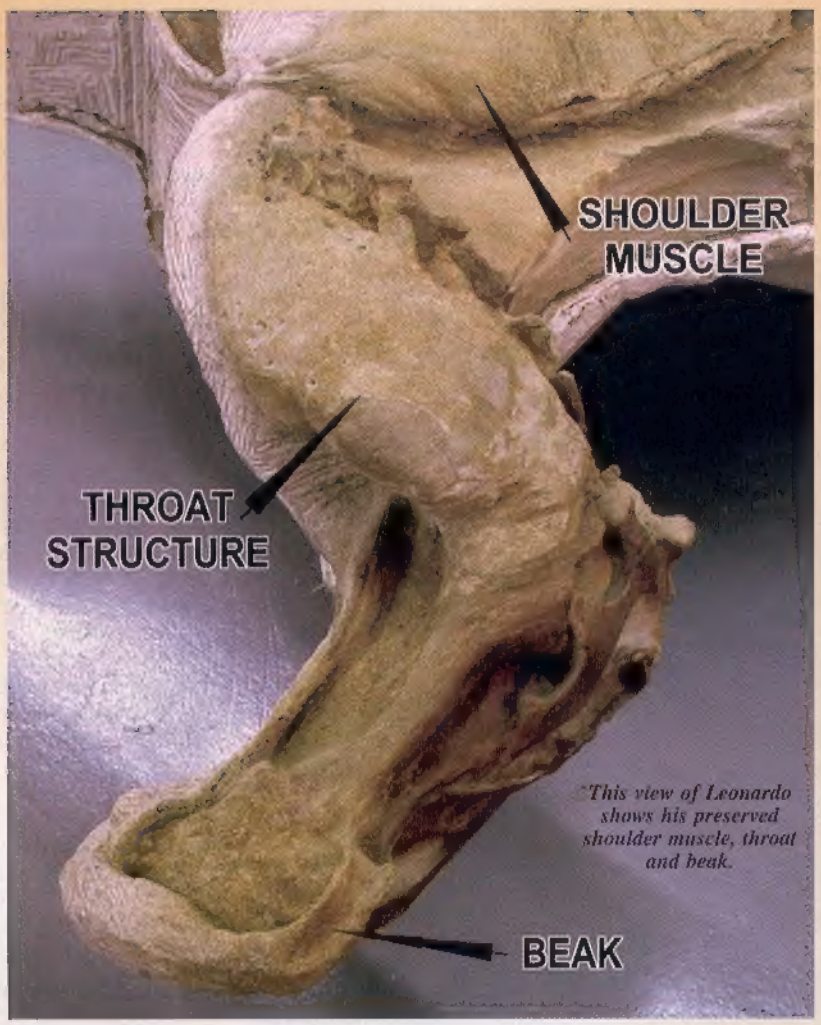
The author (right) discusses the discovery of Leonardo with Nate Murphy, curator of paleontology at the Phillips County Museum in Malta, Montana. (Photos by the author)

the Mummy Dinosaur

The World's Fourth Skin-and-Bones Fossil Find

by Squy and Bea Wallace

Leonardo was a strapping, growing, teenage duckbill hadrosaur. He started his day in a moist landscape filled with some of his favorite foods: ferns, magnolias and conifers. That morning, Leonardo ate a healthy helping of greens to support his 22-foot frame and his growing 3,000- to 4,000-pound body. After he satisfied his teenage hunger, he followed along with his herd as they approached one of the many rivers crossing his feeding grounds. The herd quietly waded into the flowing waters. Suddenly, something spooked the herd and Leonardo found himself pushed underwater as the herd stampeded for dry land. He struggled to reach the surface for air, but it was too late. Leonardo had become a victim of the river. His death was unusual because most of his fellow duckbills were more often killed and eaten by a Tyrannosaur, one of the area's carnivorous predators. As the herd moved on, Leonardo's young body floated downstream. It came to rest on a sandy bank along the shore. Here Leonardo's body was quickly covered with silt and sand, which hid it from view of the ever-present carnivores looking for a quick easy meal. Leonardo's body began to mummify, preserving his skin, muscle, beak, and soft tissue. Slowly, over time, his mummified body was fossilized. He would lie here for 77 million years, entombed in the silt and sand that had covered him.



This view of Leonardo shows his preserved shoulder muscle, throat and beak.

He quickly ran and reported his find to Nate while yelling, "We found a skeleton! We found a skeleton!"

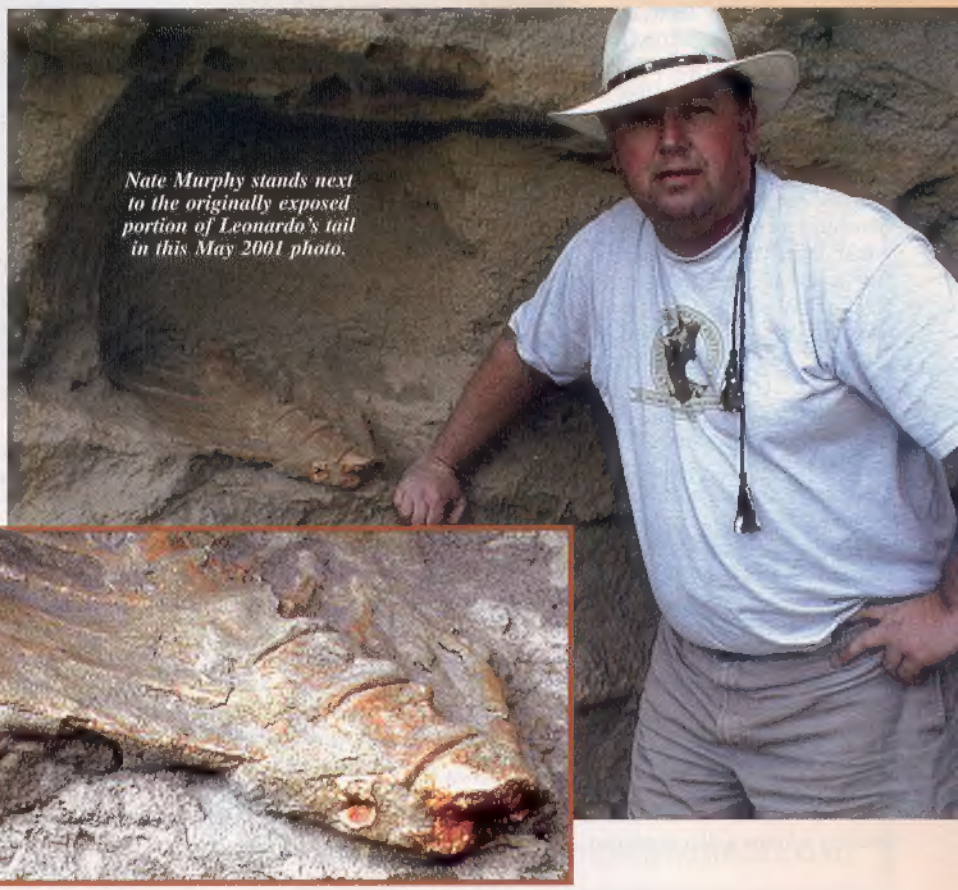
Nate said he fully expected to find an old buffalo skeleton as he walked to the site. Upon surveying the find, Nate knew that Stephenson had found a complete dinosaur skeleton, which in itself was a rare event. When he looked at the geology, he told everyone that this was a great scenario for skin fossilization. In response to the question of how the dinosaur was named, Nate related that near the fossil burial site he had found some graffiti that read, "Leonard Webb and Geneva Jordan, 1917." So he dubbed the new find "Leonardo."

Nate explained that a sequence of very complex and critical events had to occur for Leonardo to mummify before beginning the fossilization process, which took millions of years. First, Leonardo had to be buried quickly to avoid discovery by a carnivore looking for a quick, easy meal. He noted that Leonardo was found completely intact with no carnivore tooth marks or broken bones. Next, the right amount of water and minerals had to be present to prevent oxygen from decomposing the soft tissue. And last, Leonardo had to be buried in the right place so that he would be covered with the right minerals and soil that would make the fossilization process complete. "The chances of all this happening requires higher mathematics to calculate the odds," Nate said.

continued on next page

We first saw a portion of Leonardo's tail exposed in a sandstone cliff as we helped screen for the ligaments that had eroded from his tail. In May 2001, Nate Murphy, the Curator of Paleontology at the Phillips County Museum in Malta, Montana, had invited members of our Billings Gem & Mineral Club to help him excavate a newly discovered dinosaur. Little did any of us know that we would be helping excavate one of the great paleontological discoveries of the century. Frozen in the Judith River rock formation for 77 million years was a nearly complete fossilized juvenile Cretaceous duckbill hadrosaur. This subadult duckbill, Brachlophosaurus Canadensis, held a major surprise for everyone involved. He had been partially mummified, with much of his skin, beak, muscles, tendons, and internal organs intact!

In November 2002, we returned to the Phillips County Museum to interview Nate and trace the events that had occurred since our first encounter with the partially exposed skeleton a year earlier. I asked Nate, "Who originally discovered the dinosaur and how did he get the name Leonardo?" Nate was quick to tell us that Dan Stephenson of Minot, North Dakota, discovered Leonardo during the last hour of the last day of a summer expedition sponsored by the Judith River Dinosaur Institute in 2000. He added, "[Dan] had the wisdom not to mess with it."



Nate Murphy stands next to the originally exposed portion of Leonardo's tail in this May 2001 photo.

Nate went on to explain that Leonardo was only the fourth known mummified dinosaur ever to be discovered. He related the history of the first mummified dinosaur, found by the Steinbergs in 1908, that was eventually sent to the American Museum in New York. The second one found made its way to a museum in Frankfurt, Germany. And the third one lies at the bottom of the Atlantic Ocean about 620 miles from England. Nate said the British had been trying for some time to acquire a dinosaur that exhibited mummified skin. The Steinbergs had discovered one in Alberta, Canada, in 1915, shipped it on the Canadian Pacific Railroad across Canada to Nova Scotia, and loaded it onto the transport ship the MS Mount Temple in 1917. A German raider intercepted and boarded the ship about 620 miles west of Britain and then scuttled it in the Atlantic with the dinosaur specimen still encased in plaster of Paris.

I asked Nate if he would speculate on how Leonardo might have died. He related that duckbill hadrosaurs were herding animals that lived in a vast flood plain with meandering rivers. They probably traveled in herds numbering in the thousands. Just as the caribou and wildebeest travel in herds, the hadrosaurs probably waded across streams and rivers in mass crossings. As they crossed the rivers, some of them were likely spooked or lost their footing. Leonardo probably drowned in one of these crossings, since he was a juvenile and showed no signs of injury from a carnivore. We also know that Leonardo died with a full stomach. From his stomach contents, scientists have concluded that his last meal consisted of ferns, conifers, and magnolia leaves. Leonardo's masticated stomach contents revealed all this, as well as pollen from 40 different plants.

I suggested to Nate that it appeared Leonardo was a treasure trove of information for many branches of science. In this case, he contributed much to the field of paleobotany in understanding the world in which Leonardo lived. Nate said that at times, "I feel like I am on CSI [Crime Scene Investigation]." He said, "We look for all the clues we can find to solve the mystery of how a dinosaur died. It's a little bit like being a biologist, a geologist, and a county coroner. Only in this case, our victim has been dead for 77 million years."

I asked Nate, "What were some of the problems you encountered in excavating Leonardo?" He explained that normally a fossilized specimen is encased in rock that has natural fissures and cracks. This makes it fairly easy to decide how to divide and break up the fossilized remains entombed in the rock. However, in Leonardo's case, there were no natural cracks or breaks in the stone. Besides, he explained, "Where do you break up the skin on a specimen like Leonardo?" He made the decision to move Leonardo completely entombed in one unbroken, massive rock.

In May 2001, Bea, Deb and Kathy, members of the Billings Gem & Mineral Club, screened soil to search for ligaments that had eroded from Leonardo's tail.

Nate and his crew built a steel cage and suspended the plaster of Paris-encased rock on the inside. The resulting mass of steel, rock, plaster and dinosaur weighed *6.5 tons!* Nate requested an Army National Guard twin prop Chinook helicopter to airlift the entombed Leonardo to a location where he could be transported to the museum on a large flatbed truck. "The agreement was finalized on Sept. 11, 2001," Nate said. "About 20 minutes after the agreement was signed, terrorists crashed two airliners into the World Trade Center. Immediately, the National Guard had higher priorities thrust upon them. Murphy's Law was at work!" he joked. Nate then arranged for a bulldozer to flip over the 6.5 ton mass, load it onto a flatbed truck, and transport it to the museum. He said there were many tense moments involved in this effort. He said that, "I used all of the geometry and mathematics I ever learned in school to calculate the forces to safely flip and move the steel cage with Leonardo."

I asked Nate, "What has been the impact of Leonardo's discovery?" He spent a considerable amount of time explaining that finding Leonardo in the rare condition of being mummified before fossilization has had a huge impact on several sciences. In fact, some have referred to Leonardo as "the Rosetta Stone of paleontology." So much of Leonardo's soft tissue was preserved that now we know some parts of the duckbill dinosaur, such as the frill, were as "soft as our ear lobe." Additionally, the internal organs of Leonardo were very well preserved before they were fossilized. Eventually, Leonardo will be encased in a sarcophagus so he can be transported to NASA or another facility where a CAT scan and additional internal scans can be performed. If the scans reveal that he had a four-chambered heart, then the age-old question of whether dinosaurs were cold-blooded or warm-blooded will be definitively answered. A four-chambered heart would definitely belong to a warm-blooded animal.

continued on page 24

Leonardo the Mummy Dinosaur *from page 22*

Analyses of Leonardo's stomach contents already have revealed much about his diet. Perhaps more importantly, analyses of the pollens will reveal even more about the paleobotany of the Cretaceous period. For example, liverwort pollen was found in the dinosaur's stomach. Liverworts grow only in damp, moist climates. Further analyses of the other pollens will provide a more complete botanical picture of Leonardo's world. Nate added, "I could probably spend the rest of my life studying Leonardo. There is so much new information he brings to us that we will be learning from him for years to come, especially as we develop new tools to examine and interpret Leonardo's internal organs."

I asked Nate, "What's in the future for Leonardo?" He responded that he will need the cooperation from many different scientists to continue to extract as much information as possible from Leonardo. Nate said he plans to complete the final preparation of Leonardo and then prepare a sarcophagus to transport him for additional study at other facilities. Additionally, Leonardo will probably go on an exhibition tour. Also, National Geographic plans to do a program on Leonardo. For more information about the National Geographic program see http://news.nationalgeographic.com/news/2002/10/1010_021010_dino_mummy.html.

I asked Nate, "Do you have other discoveries you are working on?" He responded, "Yes, we have a complete articulated skeleton of a mature duckbill in the laboratory that we are finishing. We call this one 'Roberta.' By comparing the various stages of growth and development, we will be able to gain insights into the life cycle of the species." I asked why there appeared to be so many duckbills in the Judith River Formation. Nate explained, "The duckbills were essentially 'cretaceous cows.' There were lots of them." I suggested that this must have been a great place for the carnivores that were needed to keep the numbers of duckbills in check. Nate responded, "We can learn a lot from the relationship of carnivores and herbivores of the Cretaceous period. They appear to have a relationship not unlike the one between the wolves and other carnivores and our contemporary herbivores like deer and elk."

"Gem and mineral clubs play an important role in the world of paleontology," Nate said in closing. "By associating their clubs and members with museums and universities, they can play a critical role in helping professional paleontologists make new, exciting discoveries that will help us better understand the past."

The Phillips County Museum is located about one mile east of Malta, Montana, on U.S. Highway 2. AMTRAK follows a parallel course to U.S. Highway 2 and passes through Malta along the Montana highline. The museum is the official repository for all the specimens collected through the work of the Judith River Dinosaur Institute. The museum is open from 10 a.m. to 5 p.m. Monday through Saturday, and 12:30 p.m. to 5 p.m. on Sunday. The season runs from mid-May through mid-September. In addition to the exceptional dinosaur specimens, the museum also has displays covering the Indians, outlaws and pioneers of Phillips County. For more information, visit the museum Web site at www.montanadinosaurdigs.com/museum.htm.

Get in on the Action

If you are interested in a hands-on learning experience, you can sign up for one of the five-day expeditions sponsored by Nate and the Judith River Dinosaur Institute. The expeditions' comprehensive curriculum includes:

Hands-On Experience

- Field Exploration: learn to find new specimens and field sites
- Methods of recording and mapping finds
- Interpretation and taphonomy
- Identification of anatomy and species
- Introduction to established dig site and excavation methods
- Specimen extraction techniques (jacketing and removal)
- Avoidance of concretions and other tricks

Laboratory Demonstrations

Day five of each week is laboratory day to prepare and preserve the specimens discovered during the week. Participants will learn many paleontological methods from using hand tools to air abrasion and pneumatics.

Group Discussion and Slide Presentations

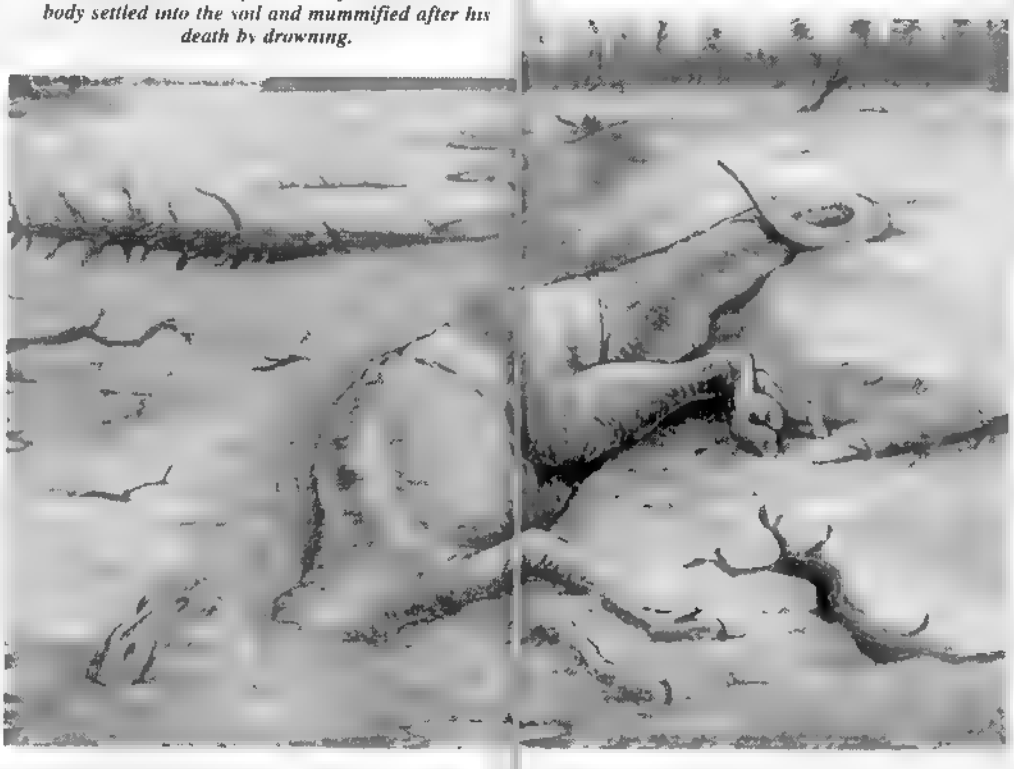
- Geology of the Judith River Formation
- The bio-sociological habits of the dinosaurs represented in the Judith River Formation
- What is known about dinosaurs and their relationships to modern animals
- The environment of the Late Cretaceous period in Montana
- What is a concretion anyway
- New insights into Geological Time

The dates for the 2003 season are:
July 7 – July 11
July 14 – July 18
July 28 – Aug. 1
Aug. 4 – Aug. 8
Aug. 11 – Aug. 15
Aug. 18 – Aug. 22

For information on the fees and how to reserve a spot in one of the expedition weeks, go to the Institute's Web site at www.montanadinosaurdigs.com.

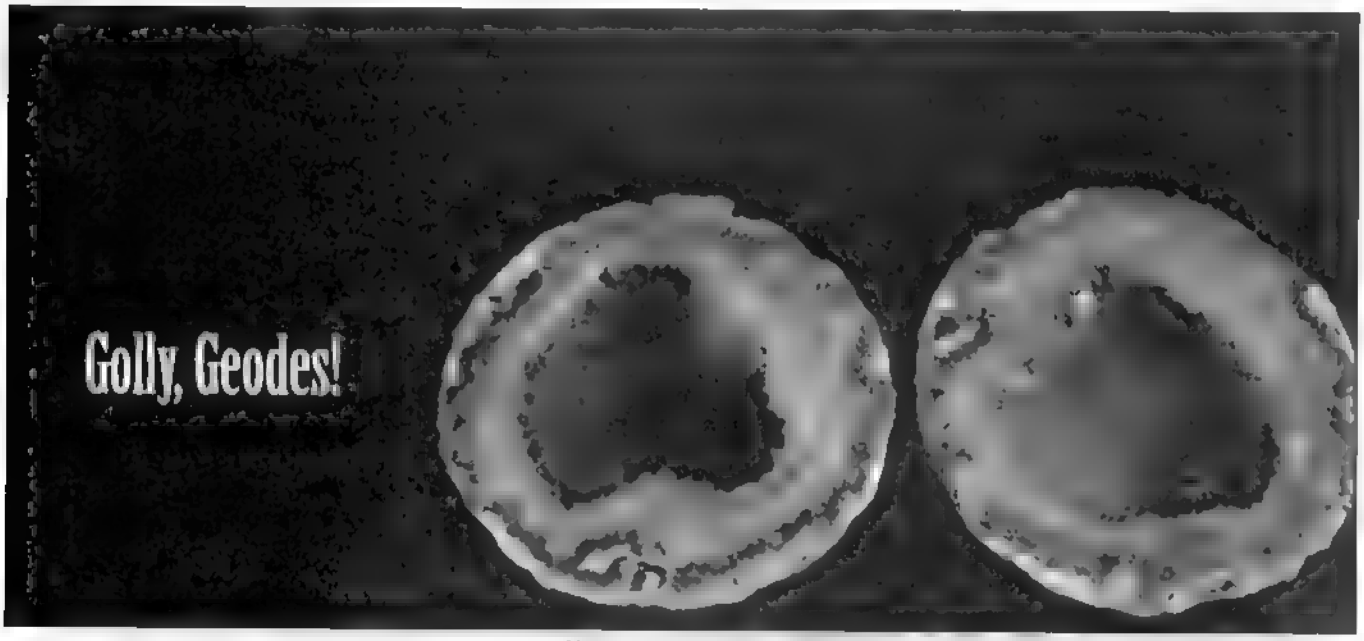
Discovering a new dinosaur is an exciting lifetime event. However, discovering a dinosaur like Leonardo is a lot like winning the lottery. The odds for the events that occurred which allowed him to mummify before being fossilized are probably one in a million. Who knows, on your next gem and mineral club field trip you may discover an even more complete specimen than Leonardo, the mummy dinosaur!

This is an artist's interpretation of how Leonardo's body settled into the soil and mummified after his death by drowning.



LAPIDARY LORE and MORE

by June Culp Zeitner



This igneous geode from Chihuahua, Mexico, is lined with agate and amethyst (photo by Henry Mullson)

Since I first became involved in the world of rocks and minerals, I have considered geodes among the most collectible rocks for both lapidaries and mineral collectors. Many geodes, mostly those found in igneous formations such as the silicified coconuts of Mexico or the amethyst geodes and polyhedroids of Brazil, are also popular with lapidaries. Geodes are nature's surprise packages. When a coconut geode is cut open, it may have an agate rim of up to 1 inch or so and a center filled with bold blades of white calcite creating geometric designs. Or there may be quartz crystals, orange goethite, black hematite, green apatite or botryoidal chalcedony, as well as a dozen or more other surprises. Opening their chosen geode has become the main attraction for children at many shows. Not only that, but many adults watching their children have somehow found themselves having more geodes and then a diamond saw, grinders, sanders and buffs. It is the thrill of opening a mysterious package and the awe of finding every one matchless that makes geodes educational and fun.

Sedimentary geodes are found in Iowa, Missouri, Illinois and several other central states and strangely, Florida. Those found in the Warsaw Formation of the Midwest are usually nearly round and have chalcedony shells filled with a smorgasbord of wonders. The lining may be sparkling golden pyrite, white quartz with pink calcite, iridescent marcasite on botryoidal quartz, yellow dolomite, blue barite or any of dozens of combinations. Perhaps the most beautiful is called diamond dewdrop for its sheltering microscopic quartz crystals on top of clear to drusy quartz. Probably the strangest are those filled with water or oil.

The geodes of Florida are agatized corals and seashells from ancient tropical reefs. Completely ugly on the outside, they have interiors that are masterpieces of modern art created by nature. Botryoidal chalcedony linings can be blue, black, orange, red-orange, yellow, white and often combinations of several colors. Sometimes the colorful chalcedony is covered with clear drusy quartz. The geodes are not round or oval. They are shaped like fans, vases, hands, liver sausages and coke bottles. Displays of these coral geodes, cut and polished, have won dozens of trophies for 20 years or more. These geodes are the best of the sedimentary geodes for the lapidary. They can be used for one of a kind jewelry, dramatic pendants or freeform natural hoops for novel earrings. They are perfect for any of the carefully popular pieces of jewelry set with glittering drusy crystals over typical inclusions. Only the sawing and polishing of the edges is needed to bring rave reviews to the lapidary.

The most spectacular are the amethyst geodes of Brazil and Uruguay. These geodes are lined with agate and richly colored amethyst crystals. They are larger on average than geodes from other areas. Some are truly enormous. I had my picture taken next to one at least 2 feet tall or than I am, and I'm 5 feet 6 inches. Lapidaries cut the geodes and polish the agate shell, but many of these geodes also provide fine faceting material for amateur and professional cutters. When heated, some of the amethyst becomes a true yellow quartz.

Perhaps the strangest of geodes are also from Brazil. Called polyhedroids, these agate geodes are shaped like triangles, diamonds, hexagons, pentagons and parallelograms, in other words, geometric lines. The high quality agate slices are white, gray, blue, yellow, tan, brown, black and rarely, fortunately, lavender.

Linings are botryoidal or drusy crystals. Most are of moderate size, 4 to 6 inches, so they can easily be cut and polished. They are showy, splashy specimens because people aren't prepared for the straight sided, geometrically patterned geodes. Some lapidaries have been reported faking them somehow, but I can't figure out how to give it a try.

Some people collect geodes, or geodes and their relatives the nodules, eggs and concretions. Geodes are found in most earth science museums and in most private mineral collections.

Eggshell chalcedony geodes from Uruguay are so thin that one can easily see the water contained in them. Lapidaries don't have to do anything with such envirdros except clean them up and have fun watch

ing the water roll around inside

The petroleum geodes of Illinois can be identified by smell Most of these bitumen filled geodes are dark on the outside, too Not even Texaco can determine how the oil got there

Years ago, many accepted the following definition of geodes "Geodes are rather spherical hollow rocks enclosing quartz crystals or chalcedony" Now we know lots of geodes are not even close to being spherical, many are filled with quartz crystals and are not hollow, although they once were The statement limiting geodes' contents to the quartz family is also incorrect If it were true, part of the mystery of opening them would be gone. The eager anticipation of opening one with rare or unique inclusions is one reason to keep looking for them or buying them to see what's inside Dealers who open geodes for their customers are sure to let them be the first in the world to see the inside of their chosen rock

While children and some adults look first at the beauty of a geode, advanced collectors may look for inclusions Here are some of the minerals that have been found in geodes pyrite, marcasite, siderite, goethite, dolomite opal, aragonite, calcite, barite, kaolinite, selenite, sphalerite, chalcopyrite, hematite, pyrolusite, smithsonite, malachite, jarosite, apatite, mordenite, millerite, rutile, chlorite, ramsdellite, rancieite, todorokite, cryptomelane, and several varieties of quartz

There are also iridescent specimens, crystal balls that look like snowballs These are interesting because the crystals on the surface of the quartz ball point outward, rather than inward like most quartz-lined geodes Other crystals resemble nail heads, dog teeth, fishtails, swords, TV antennas, and an old game we used to call "Jackstraws" No wonder kids find geodes so exciting

Not much has been written about geodes There is a book about the Keokuk geodes *The Fabulous Keokuk Geodes*, by Stephen Sinotte, published in 1969 Leland Quick mentions them in *The Book of Agates* Benjamin Schaub reviews them in *The Origin of Agates, Thundereggs and other Nodular Structures* William Sanborn has a chapter on geodes and thundereggs in *Oddities of the Mineral Kingdom*, and magazines in the field have published articles about geodes such as those of Florida, Mexico and Brazil An excellent article is by Robert Finkelman, et al., in the *Mineralogical Record*, Vol 3, Number 5, "A Scanning Electron Microscopy Study of Minerals in Geodes from Chihuahua, Mexico" John Sinkankas gives localities in his three-volume set *Gemstones of North America*

The subject of geodes is like any other part of the Mineral Kingdom The more you learn, the more you want to know

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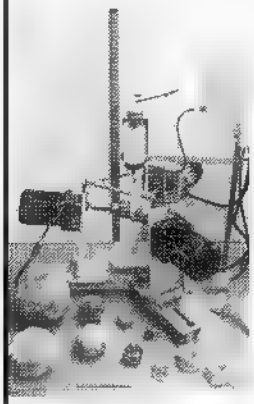

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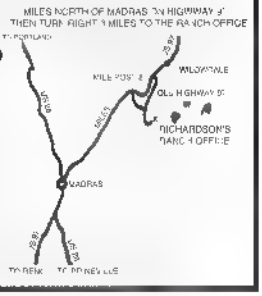

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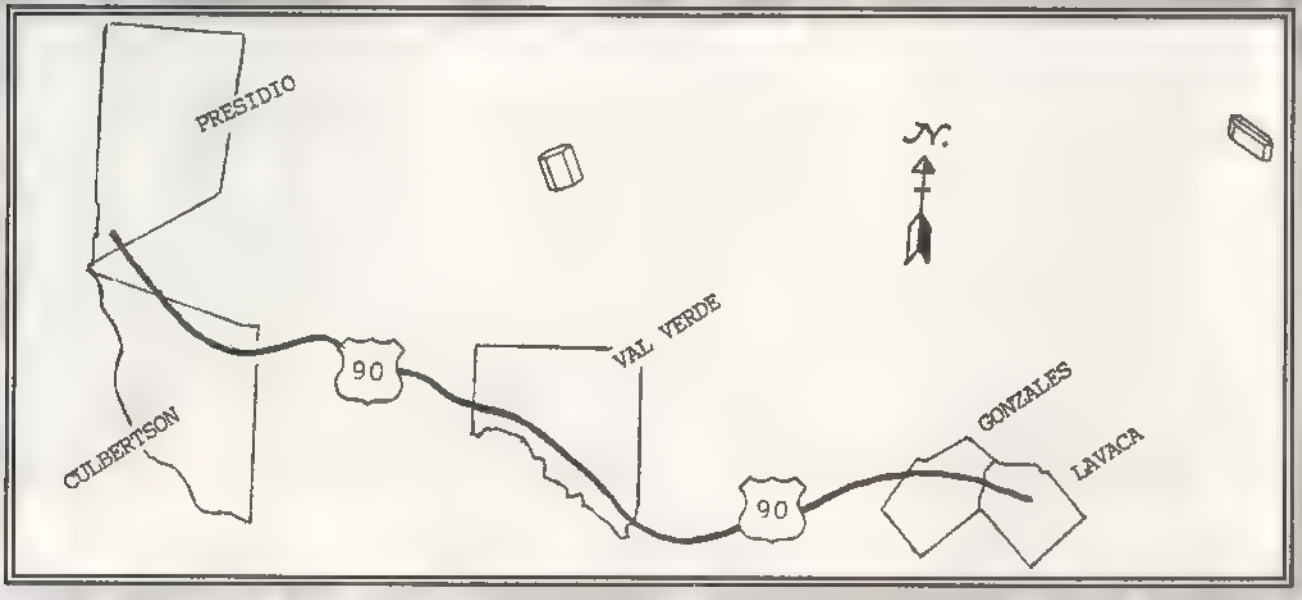
GOLD AND GEM HIGHWAYS

PANNING SITES ALONG U.S. HIGHWAY 90

Seven Easy-Access Sites in Texas



by David and Clois Walker

Whenever or wherever, erosion is forever! This expression can scarcely be underestimated in view of the geological forces that produce plains where mountains used to be, or conversely, raise mountains where plains used to be!

In any event, we're confident in our speculation that the gem and mineral deposits previously reported to exist on Texas watersheds have yet to be eroded all the way to the Gulf of Mexico! The amplified drainage network, too, in Texas is evidence enough of mineral-laden gravels still shifting about in the seasonal carriers and they doubtless still exist in some of the historical terraces, awaiting Mother Nature's intermittent gully-washers.

For the benefit, then, of those who will go along with the erosion-is-forever theory, we have listed here a number of potential panning or screening sites at selected river and stream crossings along U.S. Highway 90. They have not been confirmed by on-site observation, but are deduced from careful study of topography and reported mineral finds. We offer these public-access sites primarily as an alternative to the otherwise necessity of locating and negotiating access privileges from private landowners—a time-taking procedure even when successful.

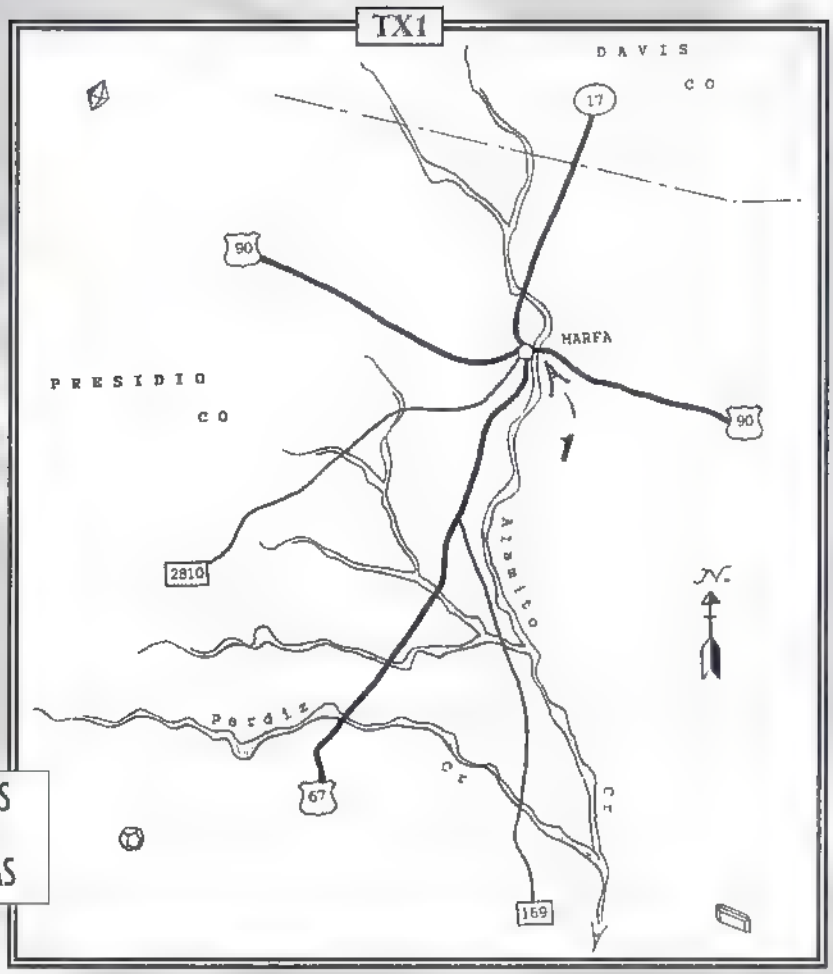
Highway patrolmen and maintenance personnel are a little more likely to cooperate with your gem-hunting activities when the usual safety and environmental standards are adhered to. Dale Carnegie's "a wave and a smile" usually goes a long way in this regard!

The corresponding, hand-crafted vicinity maps are also provided in this article provide sufficient detail for identifying the location in the field, and are rendered on an approximate scale indicative of the hydrological implication. The official state highway map of the area should also be referred to, in conjunction with the vicinity maps, for mileage and other regional planning.

So good luck, but remember [illegible] erosion pills!

LOCATION AND VICINITY FINDS ALONG U.S. HIGHWAY 90 IN TEXAS

PRESIDIO COUNTY (MAP TX1)
Site 1 Crossing on Alamito Creek, near MARFA Vicinity finds include agate, chalcedony and jasper



SUGGESTED PANNING SITES ALONG U.S. HIGHWAY 90 IN PRESIDIO COUNTY, TEXAS

SUGGESTED PANNING SITES ALONG U.S. HIGHWAY 90 IN CULBERTSON COUNTY, TEXAS

CULBERSON COUNTY (MAP TX2)
Site 1 Crossing on Chispa Creek, near DISCUS Vicinity finds indicate gold potential

continued on next page

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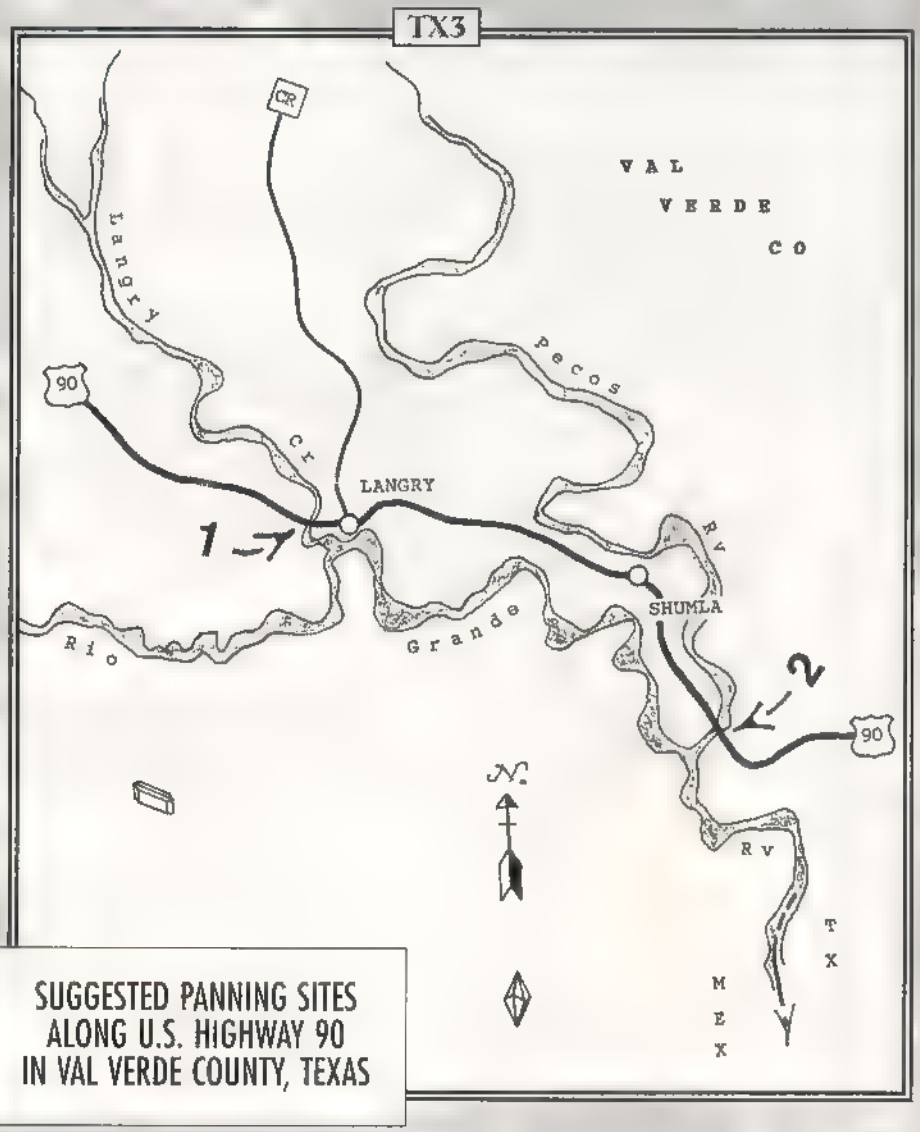
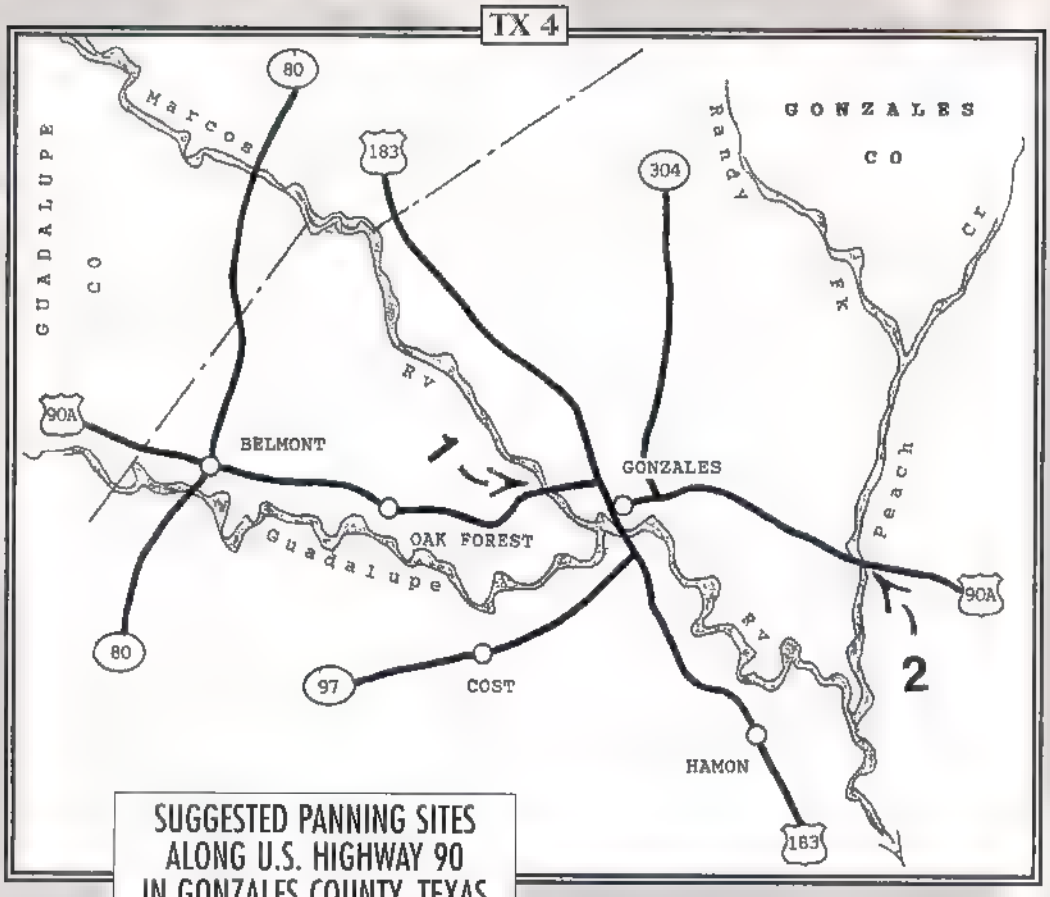
Panning Sites along U.S. Highway 90 *from page 35*

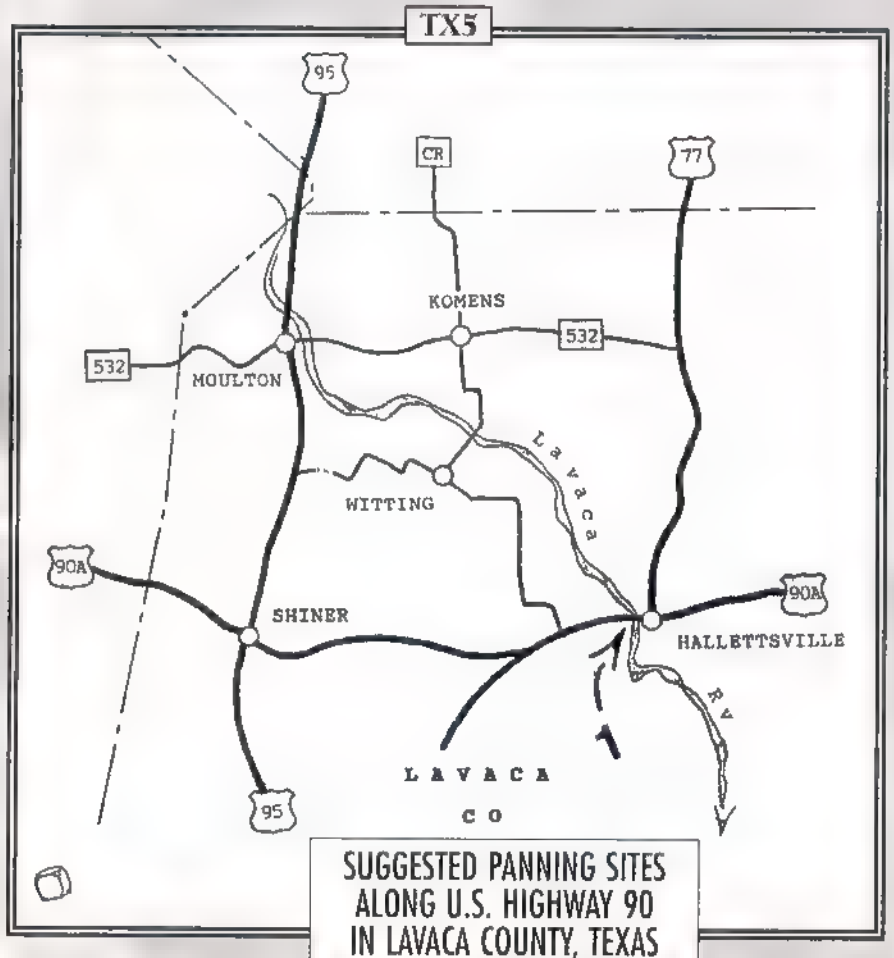


SUGGESTED PANNING SITES ALONG U.S. HIGHWAY 90 IN VAL VERDE COUNTY, TEXAS

VAL VERDE COUNTY (MAP TX3)
Site 1 Crossing on Langry Creek, near LANGRY Vicinity finds include agate and silicified wood
Site 2 Crossing on Pecos River, near SHUMLA Vicinity finds indicate quartz potential



SUGGESTED PANNING SITES ALONG U.S. HIGHWAY 90 IN GONZALES COUNTY, TEXAS

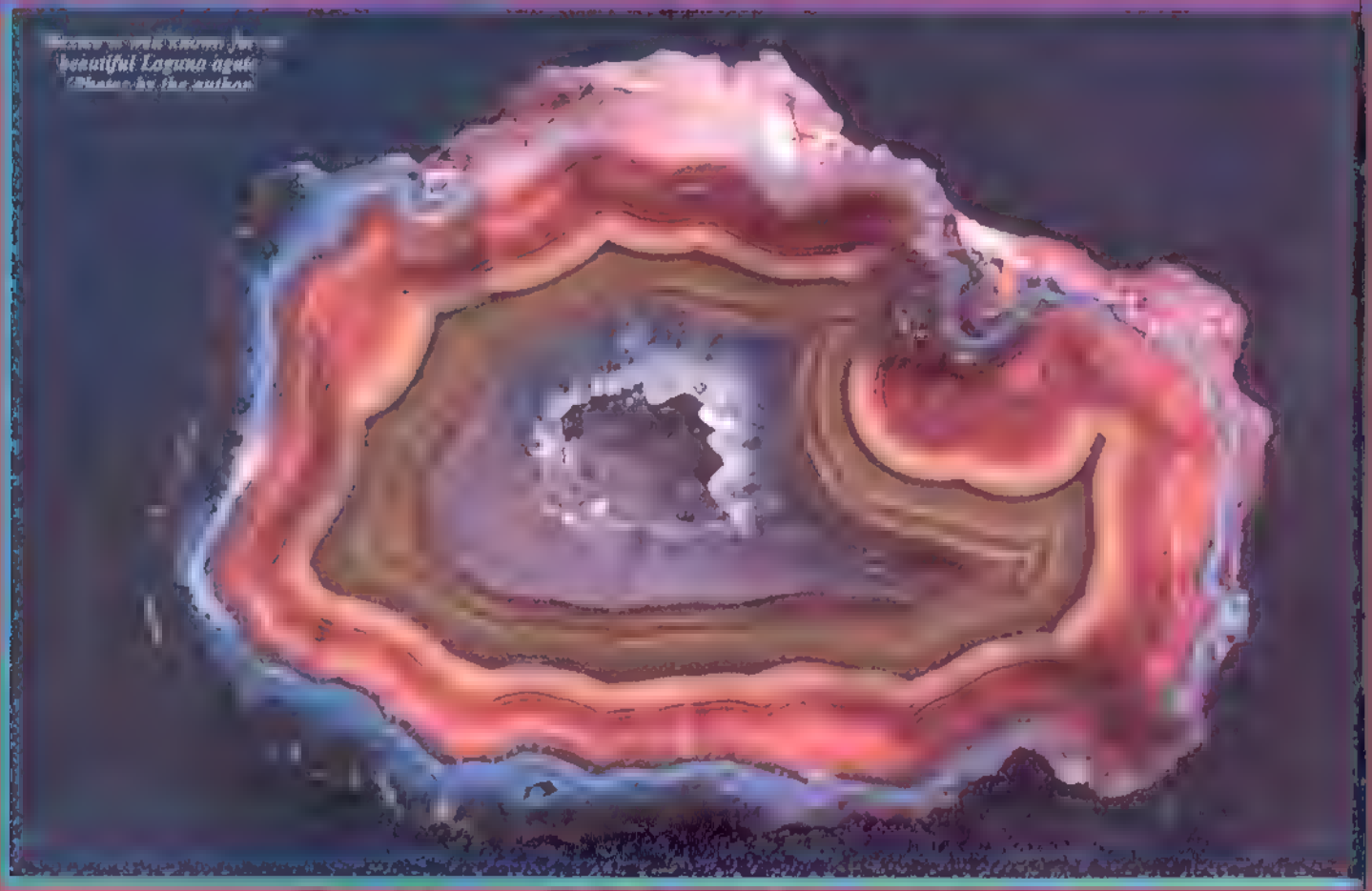


SUGGESTED PANNING SITES ALONG U.S. HIGHWAY 90 IN LAVACA COUNTY, TEXAS

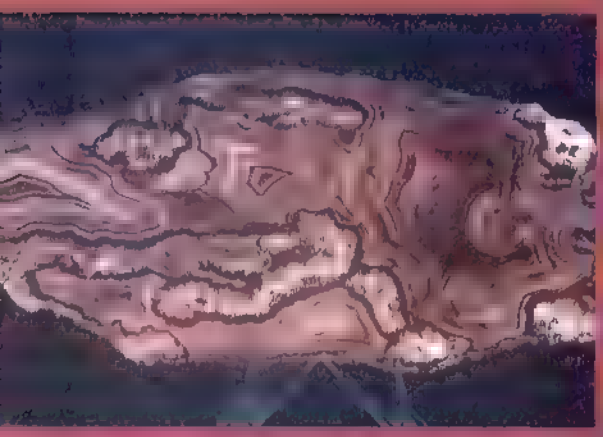
GONZALES COUNTY (MAP TX4)
Site 1. Crossing on Marcos River, near GONZALES. Vicinity finds include onyx and palm wood.
Site 2. Crossing on Peach Creek, near GONZALES. Vicinity finds include agate, silicified wood, and palm wood.

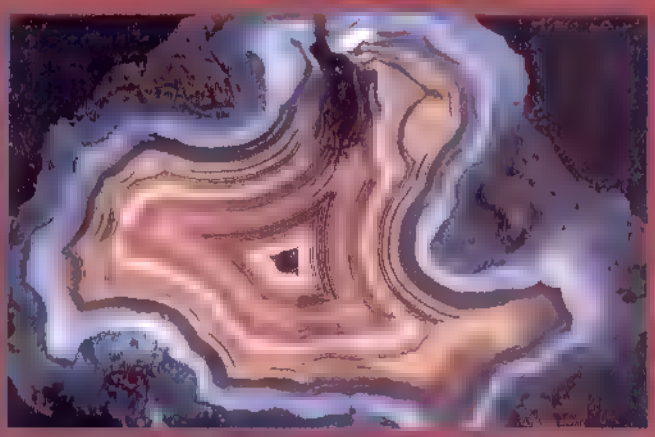
LAVACA COUNTY (MAP TX5)
Site 1. Crossing on Lavaca River, near HALLETTSVILLE. Vicinity finds include silicified wood and palm wood.

AGATE COLLEC



Rockhounds Mine a Laguna Agate Deposit Deep in Mexico





TOR'S HEAVEN

by Pat McMahan

I was 8 years old when I first looked at Professor Ade's rock collection. Seventy-five-year-old Ade Skoglberg liked to be called Professor Ade by the kids in the neighborhood. He had been collecting rocks and fossils since the '30s.

I came across a beautiful multicolored banded agate with hairy inclusions. "What is this?" I asked Professor Ade. "It's Laguna agate with sagenite." He knew what every rock was. "Where is it from?" "Deep into Mexico." Wow, I thought, my dad has told me about some of his trips to Mexico. It must be a wonderful place.

The moment of seeing and holding that rock left an impression that has stayed with me to this day and set the stage for dreams of pursuing agate deep into Mexico. This was agate collector's heaven, Valhalla, where when digging into a dirt bank, large, colorful Laguna agates rolled to your feet. This dream came true in the spring of 2002.

Gene Mueller and I were invited by the owners to mine Laguna agate on the Alianza Claim near Estacion Ojo de Laguna, about 150 miles south of El Paso, Texas. With the risks and challenges of setting up and running a mining operation in Mexico, some might think this adventure was an example of a hobby gone amuck. I'm sure they're right, but the challenges associated with this operation were dwarfed by the opportunity to collect some of the finest agate in the world.

On this trip to agate heaven, we would use the most efficient digging machine ever used to locate these Laguna treasures, operated by an expert machine operator who probably knows more than any other agate prospector that has dug the Laguna deposit. The groundwork was laid and the stage was set for the agate collector's ultimate dream.

Gene, owner of the Gem Shop in Cedarburg, Wisconsin, has been importing Mexican and other agate for many years. He presently is the sole U.S. importer of rough Ocean Jasper from the Paul Obinach mines in Madagascar. He had dreamed for many years of mining Laguna agate. In his pursuit of fine agate and jasper, Gene learned some years ago how to operate heavy equipment. His digging machine of choice is a Caterpillar 320 Excavator. This is what we used.

I first visited the Laguna agate deposits about seven years ago with Gene. Fascinated with the beautiful sagenite and plume agate – my main focus – I began wondering how we could be involved in the mining of this material ourselves. After numerous visits and contacts with the Mexican mining officials, Mexican attorneys, land owners, claim holders, the Mexican Consulate, insurance companies, immigration and naturalization officers, import brokers and a few others, we finally cleared the way to buy a small trailer and start packing our bags for the six-week dig.

We had to consider many needs in our preparations, but menu planning posed a challenge of its own. We would be 60 miles from the nearest city, and a half hour's drive from the town of Estacion Ojo Laguna and the very limited supplies available there. We also didn't know whether or not we'd have to provide three meals a day for our two helpers. My goal was to be completely self-contained, and my many years of experience of camping in Baja California and other parts of Mexico told me to have plenty of food for unexpected guests, as no restaurants would be near our camp. Shopping at Costco and Sam's Club proved a big help.

We each took a small travel trailer, food, water, mining tools, and at least three pages' worth of other stuff. Arriving at Ojo Laguna, we left one of the trailers and took Gene's truck to Chihuahua City to pick up the Caterpillar excavator. A truck hauled it to within three miles of the mine.

Early the next day, Gene started repairing the road to the mine. Armando, his son, Lalo, and I walked behind the machine with picks, pulling up mesquite bushes with thorns up to 2 inches long, which would easily flatten any four-ply tire. This turned out to be one of the longest weeding projects I had ever been involved in. The bends in the road had to be widened, boulders removed, and the grade reduced for the last 150 yards before camp.

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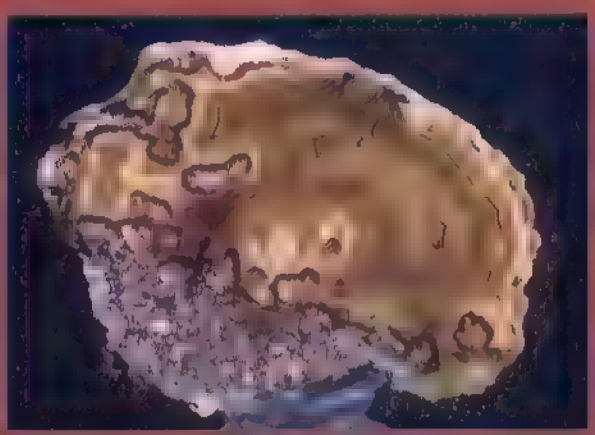

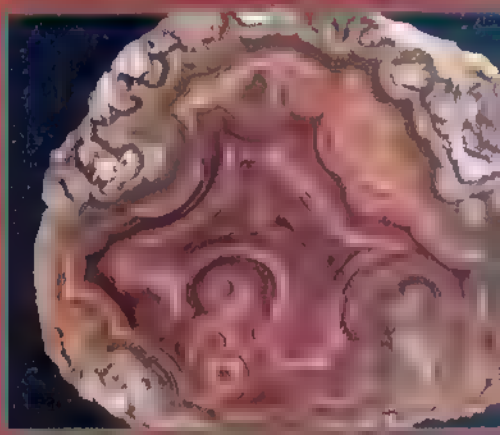

Agate Collector's Heaven *from page 41*

Our campsite was one of the few flat spots in those mountains, which rose more than 2,000 feet above the valley floor. Care was taken to remove as few prickly pear and other cacti as possible to make room for the two trailers. We soon discovered we weren't the first humans to occupy this camp. Ancient skinning tools and broken arrowheads practically littered the ground. Our camp was adjacent to a mountain pass where hunters of another era must have lain in wait for prey.

Once the campsite was leveled, a loading dock built for the fuel barrels and brush and cacti moved, Gene took the machine a quarter-mile farther to the mine site. The road needed much work and once at the mine, a road had to be built for the machine to the area where we would dig agate. Overburden had to be cleared for access to the agate-rich layers of rock and ash. A day and a half of work lay ahead for the machine before we could find our first Laguna agate.

While chomping at the bit, I had a chance to utilize our work crew to make our campsite more comfortable. The three of us cleared all the brush and cactus stickers and built a wind-protected camp fireplace, complete with the necessary flat rocks to set pots and skillets on and such. We also laid gravel for a 15-foot radius around the fireplace to keep dust from blowing into the food and prevent grass fires. Nearly a cord of wonderful mesquite firewood was gathered, cut and stacked, along with dry grass and kindling for starting the fires.

Next, and very important, was the commode. A deep hole was dug, flat rocks were stacked on each side, and the crowning touch, a toilet seat, was added. A 100-foot trail was made back to the trailers. We parked the trailers so the refrigerators were facing north where they would receive the most shade. We then built a rock monument where two 20-gallon water barrels were placed. Holes were dug for the trailer sewers, and finally the camp was set. We were ready!

Our mining started on March 15 as Gene approached the last 100 feet of road building to where we believed the best agate at the Alianza claim was. He had hit very little agate on the way up. About 50 feet from the top, we found a few nice agates. The excitement was mounting. Armando, who has worked this claim by hand for 40 years, marked prime agate locations at the mine with orange flag tape. He and I found a few choice pieces in the marking process. There are some wonderful agates here.

A full day of preparation work at the mine followed. The road to the agate deposit was completed and a pad for the machine was made. In digging the pad we located some agate. After a dinner of barbequed steelhead trout, fresh broccoli, and halved onions with butter and garlic wrapped in aluminum foil, we shared our excitement for the next day over our first campfire.

Gene Mueller (left) and Pat McMahan (right, had the adventure of a lifetime when they mined a Mexican lace agate deposit for six weeks. (Brad Cross photo)

Gene and I awoke with more excitement than the average person should experience. After a great breakfast of pancakes and bacon, at 8 a.m. we were on our way to the mine to dig in what we believed might become one of the best areas on the Laguna Ranch.

Gene soon struck an 8-ton boulder. Though he was determined to move it to get to some good agate, the rock won and took an outside tooth from the excavator's bucket and inflicted a number of structural cracks. I called the rental company and tried to get a new bucket. This was the first of several problems with the bucket, which shut us down for nine days during our dig.

The next day we moved a lot of dirt and rock and ended up with about 150 pounds of agate. Only about 20 pounds of this agate was #1, including a fabulous tube agate with wonderful, banded eyes. (#1 agate is any nodule over 2 inches with color, of which 75 percent will cut a full pattern. #2 agate is under 2 inches in size with a full pattern and colorful or exceptional color with a broken pattern. #3 may have a broken pattern with possibly one color. #3 often makes excellent cabbing material.)

Sunday, March 17, was our light day. Our trailers had settled with the 40 to 50 mph winds rattling their frames, so some adjustments were necessary to re-level them. Sleeping in the trailers during these high winds was like being in an airplane in turbulence. We cleaned up camp, repaired the latches on my trailer door, and gave attention to food inventory. Gene hiked up the hill to the south opposite the mine to take "before" pictures.

I left camp in search of the source of some plume we had found the day before. I found some sagenite with black needles in white to clear banded agate. I traced the plume float to where it disappeared and picked up a few good pieces. Prior hand-digging and earth movement made it difficult to pinpoint the plume deposit.

Gene and I were back at camp by 11 a.m. for lunch, and went back to digging with the machine until 5:30 p.m. Our work netted one good agate and 50 pounds of #2 and #3, mostly red moss with some banding and a few nodules. We needed to find more concentrated areas of nodules—pockets or veins with good agate would be wonderful. We knew they were here. We would surely settle for that dirt bank where the nodules rolled out on your feet.

On March 18 we dug a hole 50 feet wide, 15 feet front to back, and 12 feet deep which produced only 300 pounds of agate, including a scant 15 pounds of #1. Some of the digging was slow due to hard rock. We decided the Mexican agate industry could not survive on such little production from such quantity of dirt moved. It appears the Mexican miners with hand tools had not only taken the easy-to-get material, but much of the hard-to-get also.

The following morning we found some stalactites and six or eight awesome agates. The quality was spectacular, we just didn't see the quantity. It is clear why this agate is so expensive.

The Caterpillar repairman arrived March 21st to fix the machine's bucket. Gene had dealt with Caterpillar in Idaho. There they send out a highly trained technician in a clean blue uniform with his repair truck—complete with a welder, a steam cleaner for your engine, and every spare part imaginable—all within 24 hours. Somehow, my gut (considering my experiences in Mexico) told me to look for a man on a horse with a hammer, mañana. Only a half-hour late, a small truck appeared carrying three people, a portable welder and one piece of 3 inch by 30 inch plate steel.

I left for Chihuahua City and the nearest gas station 60 miles away. Five hours later I returned to see the mechanics were done welding. The welding job didn't hold.

When I arrived at the mine after using my cell phone to try to get some more assistance to repair the twice-broken tooth, Armando was extracting a nice red and white #1. I thought things would turn around. Production was slow, but major rocks were moved, allowing the machine to get lower in the hole and to continue toward the center of the deposit. So it was a good day from a mining standpoint, but not from a production standpoint.

The day's digging revealed some nice agate. The hard andesite we were working in was loaded with tiny nodules and occasional larger nodules. Rocks up to 3 or 4 feet across had to be broken with sledgehammers and points and nodules were extracted. People who do bad things in life go to prison and break rocks like we're doing. Sometimes I think this is a crazy thing we do.

On March 24, we spent three hours removing dirt around a 6 foot-diameter rock. Behind it was a vertical calcite vein and a rich soft area that had a concentration of agate nodules. It appears there was a fault, which provided an area where water could carry and deposit silica. Moisture stopped at the rock barrier and agates were formed in the moist environment along with the calcite.

After a long day of digging, we ate pasta with alfredo sauce and watched a movie in my trailer. Don't tell anyone that Gene watched a movie while mining. Somehow that doesn't fit the rugged miner image.

March 26th was a great day! Fifty pounds of #1 were dug. We needed that

continued on next page

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Agate Collector's Heaven *from page 43*

day. Most were found in nodule laden andesites, but some in soft, claylike material. Professor Ace would have been proud. It appeared that the concentrations of agate were where water had accumulated next to impermeable rock layers, along fault zones where springs had occurred. Often calcite veins crisscrossed agate-bearing earth.

On March 27, Lou Wasty and his friend Jim came to visit. Both are avid collectors and were great company. They helped out at the mine and joined us for a nice steak dinner with good conversation around the campfire.

The next morning, Caterpillar delivered and installed a new plate with six new adaptors for the teeth on the old bucket. The teeth they brought were the wrong size. We would have been broken down five more days unless we could find teeth of our own. I called Caterpillar in Odessa, Texas, and arranged for six teeth to be delivered the next day from Denver to El Paso.

I took our dirty laundry and went to El Paso to pick up the teeth. We were back in operation the next day with new teeth and clean clothes. The teeth were installed and we worked in 40 mph winds for two hours until it was almost dark.

The dust and pebbles blasted us horizontally from the sides of the hole. When Gene dumped a bucket of dirt, the wind sometimes threw it back at him. Small rocks rolled in our ears and stuck in my newly grown beard. Our eyes blurred with the grinding dust.

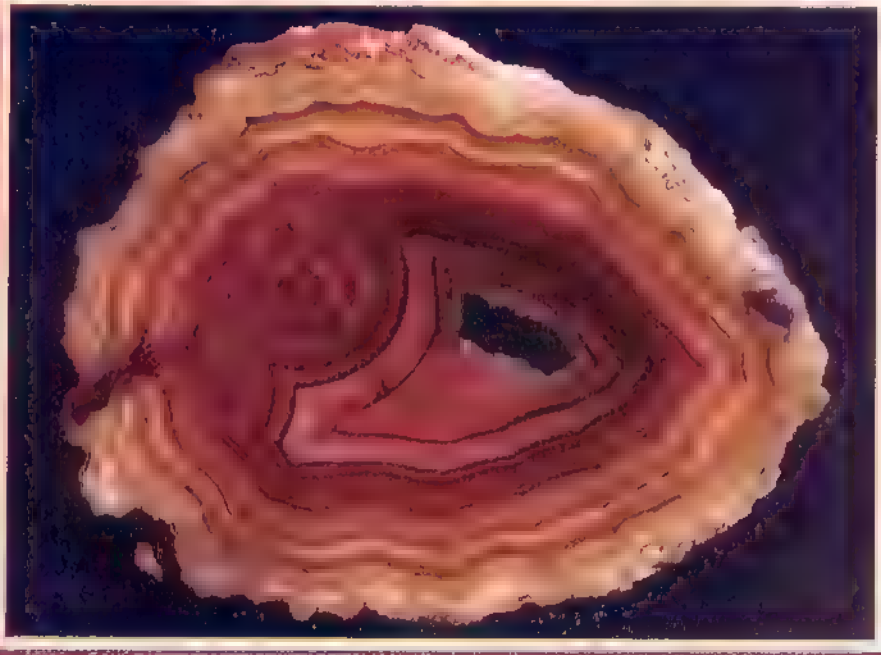
On March 30, we decided we needed a change in our game plan. We had moved a lot of dirt for three #1 agates at the very bottom of the hole. We were mining very few agates. Typically, two of us stood on one side of the bucket and one person on the other. We sometimes found only half an agate, but we usually found the other half shortly after. We were being very thorough. Gene and I were uneasy with our poor production, as we were more than halfway through our trip. We decided to move the machine to two other areas in the mine.

Gene left early for the mine the next morning. It's really nice to have a partner that works so hard. I sorted and cleaned rock until Armando and Lalo showed up at 8:30 a.m. We worked the new area and found about 30 pounds of round nodular baseball size agates, which were pink-red and purple.

April 2 was a dusty day. The top layer of earth we were working was dry, and with each scrape of the bucket, high winds swirled the dust around, making it nearly impossible to see the agate. The temperature was rising as the days got longer. The daytime temperature was about 85 degrees with an occasional, welcomed cloud.

On April 3, the bucket broke again. This time, the whole front bent open. I called Caterpillar and they brought a new, narrow rock bucket. This was easier for digging rock, but much slower for moving earth.

With the bucket broken, we took time to explore other nearby agate claims. We hiked to the north end of the Arantza claim to a hill called Punta de Las Hermosas. The Point of the Beautiful Ones. About 25 years ago, fine, wonderful, multicolored, banded agate came from this hill. The name alone excited us. We wanted to see if mining it would make sense.



We awoke the next day with new enthusiasm. With the new rock bucket, we were able to work different and difficult rocky areas. Gene's first challenge was a 1.8 to 2 boulder that broke the old bucket. He pulled on it slightly with the new rock bucket, and it easily came forward. We continued to work the same area all day and before dusk moved to a new area below our original hole. A cave that had been hand dug here years earlier produced beautiful purple banded agates with white snowflakes.

The following day, Brad Cross, author of *Agates of Northern Mexico* and the Hector Carrillo family visited around noon for a short time. Brad was impressed with the operation. Hector owns the Mexican coconut geode mine and he and his wife, Jeanette, own the Gem Center Rock Shop in El Paso. The Carrillos had never been to Laguna before. They were also favorably impressed with the operation.

On April 9, we split pieces of rock and drew straws. The rock was packed 20 kilos to a bag. Most of the agate crossed the border with a licensed broker before we left.

The following day was a good production day. Caterpillar delivered new teeth to the rock bucket. Once back at the mine, we found a good vein, which we chased off and on all afternoon. We found nodules mixed in the same rock from time to time. Some pieces of vein were 3 inches thick. We ended up with about 100 pounds of agate, 50 of which were #1.

The next day we drove the Cat to the El Agua Claim four miles away, to dig test holes. We had made prior arrangements with the claim owners to work the mine for an extended period of time if our one-day exploration was fruitful. We dug five holes which netted very little #1. Our total tally was about 50 pounds of #2 and #3. Overall the agate was not as colorful and the bands were not as well defined as Alianza agate.

We dug up on the top of the Amanzo claim, finding about 20 pounds of #1, plus nice crystals and druzy, which I carefully packed in boxes. Preparing and wrapping these crystal specimens seemed to take a lot of time. It's easier to throw agate in a bucket than go to all the trouble mineral people go through.

April 18 was our last day of digging. I stayed in camp for two hours packing, cleaning up camp, and filling sewer holes, then went to the mine to check for stray tools and clean up any trash. Our final tally was 525 pounds of #1 and 1,500 pounds of #2 and #3.

The next morning, we left early and crossed the border successfully. It was a wonderful trip, an adventure, an agate collector's ultimate dream. Now I start a new adventure in cutting. I can hardly wait for these nodules to drop from the saw's vice. Wish me luck.

Pat McMahon can be reached at 1035 Soldier Pass Rd., Sedona, AZ 86336, (928) 282-7245, e-mail: mcmahan@sedona.net. Web site: www.agateswithcharacter.com. Gene Mueller can be reached at www.thegemshop.com.

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MUCAIA:
A MODERN GEM MINE

The topaz crystals mined from Mucaia are colorless. Heat treating brings out the colors. (Photos by the author)

Modern geological methods and machinery are employed in the main pit of the Mucaia Mine.

Company geologist Marcio Kahwage (left) and mine manager Guto Liberato (right) guided me on my tour of the mine facilities.

A State-of-the-Art Source of Brazilian Topaz

by Bob Farrar

Regular readers of *Rock & Gem* will no doubt have read of gem mines all over the world. A few of you may even have read some of my accounts of mines in Brazil (June 1996, November 1998, November 1999). The impression one gets from reading about gem mines in Brazil and other developing countries is that most are low tech, pick and shovel operations where miners toil under the most primitive of conditions. In my travels to Brazil and other places, I have seen mining operations that are just that. On a recent trip to Brazil, however, I had the opportunity to visit a mine that is just the opposite—a thoroughly modern operation utilizing modern geological methods and machinery with a well-treated force of workers. It is known as the Mucaia Mine, and it is becoming a major source of topaz and, soon (hopefully), of aquamarine.

My travels to Brazil have been arranged through Sara Mount of Brazil Gem Tours. I have been traveling with Sara for years now. While I have been with her to other places, including Morocco and Thailand, Brazil is the destination that I have come to love the best. There seems to be no end to the interesting places for a rockhound to see in Brazil. Over the years, Sara has developed the kinds of connections that allow her groups to visit many of these places, including mines such as Mucaia. Our local guide in Minas Gerais, Harold Wallner, has great knowledge of the gem and mineral localities, mine operators, and dealers. He handles the details of our visits to mines such as Mucaia.

The Mucaia Mine is located the heart of Brazil's gem pegmatite country, about 40 miles north of the town of Teofilo Otoni, in the northeastern part of the state of Minas Gerais. Teofilo Otoni is about an eight-hour drive northeast of the city of Belo Horizonte, the state capital, whose airport is served by numerous flights daily. The mine is in the Marambaia District, near the small village of Cataji, and a point on the road known as Ponto do Marambaia. This mine is reasonably accessible as Brazilian gem mines go. It lies only a few miles off the main road between Belo Horizonte and the large city of Salvador, Bahia on the east coast. Only the last couple of miles are a bit rough, with some steep dirt roads to be negotiated.

The Marambaia District has long been famous for gemstones, especially aquamarine and topaz. It was at the Pipa Nel Mine in this area in 1910 that one of the most famous aquamarine discoveries was made: a 244-pound gem quality crystal. Its discovery precipitated a great deal of prospecting in the area, which continues to this day. Over the years, literally tons of aquamarine have been found. Aquamarines from this area are among the best color and quality in the world. They can also be of large sizes, the Smithsonian Institution has a 911-carat cut stone from the Marambaia District. The entire region is rich in pegmatite deposits, though particularly rich in aquamarine and topaz, other varieties of beryl, tourmalines, chrysoberyl, quartzes. Many other gems and minerals are found in the Marambaia District.

continued on next page

Large smoky quartz crystals are also found in the mine and are of some economic importance.

Curiosities from the Earth

rare and one-of-a-kind gems and crystals our specialty write for current list

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MUCAIA: A Modern Gem Mine *from page 53*

Workers pick through washed gravel to retrieve the colorless topaz crystals.

Geologically, the Mucaia Mine is in a classic granitic pegmatite, like many in the area. Some 490 million years ago, magmas intruded into much older Precambrian-age gneisses. These intrusions formed numerous granitic bodies that are today exposed as rounded exfoliation domes, which are the most prominent features of the landscape in Minas Gerais. These same magmas also formed pegmatite bodies, many of which are associated with exfoliation domes. As is typical for such formations, the pegmatite at the Mucaia Mine has as its major components quartz, feldspar and mica. This pegmatite, though, also contains significant amounts of topaz and beryl, as do others in the area.

Interestingly, while beryls, such as aquamarine, and topaz may be found in the same deposit, they are not formed in the same pockets. As we shall see, gem production at the Mucaia Mine reflects this. The pegmatite formation and the host rock at the Mucaia Mine are both highly weathered, to depths of hundreds of feet. It has not, though, been eroded by flowing water, all of its components are still more or less in place. (Other pegmatites in the area have been eroded, forming extensive alluvial deposits that have yielded much gem material.) The weathering process has turned the feldspar to soft kaolin, leaving the quartz and other minerals loose. Many of the pegmatites of Minas Gerais are deeply weathered like this. Other pegmatites, though, are not highly weathered, requiring hardrock mining to extract the gemstones. Such is the case at the Golconda Mine, near the city of Governador Valadares.

Gemstones have been mined in the Marambaia District for many years. In the past, however, much of the mining has been carried out by independent prospectors, or garimpeiros, working alone or in small groups. This is a somewhat haphazard process, and results are often hit or miss. Miners would find a spot that looked promising (perhaps showing quartz and mica on the surface), and dig into it with hand tools, or perhaps a backhoe if they could afford it, until they found something, gave up, or ran out of money. That 244-pound crystal is said to have been found by garimpeiros who dug only about 3 feet into a pit abandoned as worthless by another garimpeiro. (Remember this when you are collecting at what appears to be a well-worked site!) While much gem material has been found, there is still the prospect for much more. Recently, the company that operates the Mucaia Mine decided that the way to exploit this potential was through systematic exploration with modern methods.

It conducted a thorough exploration of an area of some 30 hectares (about 75 acres) using modern geophysical methods. Initial exploration was done seismologically. This method is similar to that used in exploration for oil. Basically, vibrations are generated that travel into the ground and are measured as they reflect back off of various formations in the Earth. Readings were taken along tran

sects across the area. Data were then used to construct maps of hidden formations underground. In this way, the company was able to locate what it believed was the core of a major pegmatite formation a couple of hundred feet down. It then used core drilling to verify that this was indeed a weathered pegmatite body, and developed an open-pit mine at this site. It was this mine, now in full operation, that we were able to visit.

Our guides for the tour were the manager, a mining engineer named Guto Liberato, and a company geologist, Marcio Kahwage. Two more hospitable and enthusiastic tour guides you will not find. We began at a small complex of tidy concrete office buildings with landscaped yards, quite unlike some of the shacks of sticks, mud and plastic that I've seen at other mines. There, overlooking the mine, we were given an explanation of how the mine was developed and shown some of the material that had been found. From there, it was a short hike down to the mine.

The pit is presently several hundred feet long by a few hundred feet wide and is a couple of hundred feet deep. Visible on the walls are a number of old tunnels that were cut through in digging the pit. These tunnels are small, just wide and high enough for a man, perhaps with a wheelbarrow, to pass through. All were hand-dug by garimpeiros, some as many as 40 or 50 years ago. The whole area seems to be honeycombed with them. The present systematic exploration, though, is proving to be a more efficient way of extracting the gems.

The day we were there, miners were digging into gem-bearing material with a small backhoe and loading the rock into a dump truck to be hauled out of the pit. The material is then put through a mechanical screening and washing system. The mud is washed off the stones, which are then sorted by size. The wash water is pumped to a settling pond to be recycled. Gravel of the size likely to contain gems (up to a couple of inches) is then spread out on the ground and picked through by hand. (I guess there's no machine that can efficiently separate quartz from topaz.) When we were there, some half dozen workers in neat company coveralls were picking through the gravel. They had a good handful of topaz that they had found in the past hour or so.

Presently, the main mineral of interest being mined is topaz. The material being dug at the time, we were told, contains about 20 grams (100 carats) of topaz per ton. Some zones, however, contain a much higher concentration of topaz. For example, one weathered pocket, still vaguely visible high on the wall of the pit, contained 5 to 6 kilograms of clean, gem-quality, terminated topaz crystals. The operation can presently process about 80 tons of material per day. It is estimated that there are about 15,000 tons of gem bearing material remaining to be processed. You do the math.

The topaz being produced at the Mucaia Mine is generally colorless. Colorless topaz is of little interest as a gemstone, so the material is being treated, first irradiated to turn it yellow, then heated to turn it blue. While practically all of the blue topaz on the market is treated in a similar manner, the material from Mucaia is considered to be among the best in its response to treatment.

While topaz is the main product of the Mucaia Mine at present, the company is hoping for much better—aquamarine. Some of the older workings in the Marambaia District have produced hundreds of kilograms of aquamarine. As I mentioned, aquamarine and topaz are not formed in the same pockets. The company is hoping that as it digs deeper, it will begin to hit zones bearing aquamarine. With a good aquamarine being worth many times the price per carat of blue topaz of similar quality, this will be the bonanza that the mine was developed for. Other minerals of some economic importance include large smoky quartz crystals and kaolin, which is used in industry.

In addition to using modern mining methods, the company is very progressive in its labor relations. The mine employs 18 workers, who work eight-hour days, six days per week. They are provided with medical insurance, childcare, and work clothes. (That's better than some American companies do!)

After viewing the mine close up, we returned to the office for a few more words of explanation, a brief rest, and a drink of cold bottled water. Our gracious hosts even provided a snack: fresh cheese served with doce de leite, a caramel-like spread. Eaten together so that the cheese cuts the sweetness of the spread, this is a favorite dessert in Minas Gerais. On our way out of town, we stopped at the company day care center for a brief visit. They care for some 54 kids. (Large families are common in Brazil.) The facility is very basic, but I expect that they are able to provide the kids with better care than most miners' kids in Brazil would get.

The Mucaia Mine has been developed using some of the most modern methods employed in the gem mining industry of Brazil. This large scale, systematic approach promises to keep the Marambaia District a consistent producer of fine gemstones for years to come. ♥

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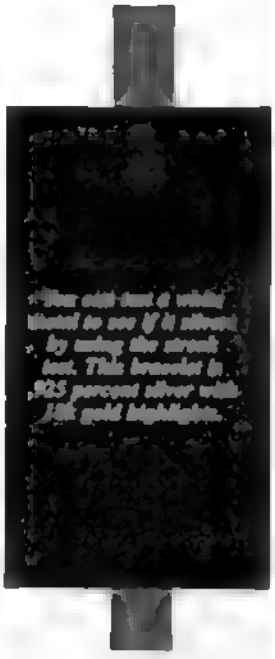
GEMOLOGY:
Learning the Craft

Part V: A Gemologist's Field Trip

by Douglas S. Le Grand G.G.



stone. Be careful that you are not seeing double images from the facets of the stone. With a little practice, you will be able to spot single- and double-refractive material with the best of them.

Another device I use to detect single- and double-refractive material is simple to make out of a piece of flat cardboard and a pencil. Fold the ends of the cardboard down at 90 degree angles and cut a small hole in the center. Place the stone table down over the hole and hold your pocket light directly above the stone. You will see a circle of images formed on the table beneath your homemade box. Focus the images by moving the light source up or down until you see a clear pattern. Again, if you see a doubling of light bulb images, you have a double refractive material. If you see a single image, then you have a single refractive material. The stronger the doubling of the image, by this I mean the farther apart each image is separated, the higher your refractive index. This will actually help you determine the nature of the material as well as whether it is single- or double-refractive.

These tools are used for quick identification of stones offered by a reputable dealer. If a dealer is reputable, then what is the problem? Many rough dealers buy their material in bulk (1,000 gram lots). This means a lot of stones to sort through. If you buy from this person's bulk pile, you can usually save money and find the exact stone you want. If you buy from a dealer who is only showing you one or two specimens of a gemstone, you will pay a premium because he has already sorted the material out and is selling only the prime, hand-selected pieces. Both of these types of dealers are out there, and sometimes the same dealer will be selling to two different types of buyers; this is known as "perfect monopoly." Which one you should buy from should be based on your level of expertise and your relationship with the dealer. I will stress relationship with your dealer because, in the end, this is what makes the difference in you being successful.

If you are a hobbyist looking to cut one nice, large stone, then I recommend buying from the dealer who has already selected his finest samples to sell. If you establish a relationship with this person, he will soon learn what it is you are looking for. Gem dealers are like any other business owner; they want to make a living selling. To make a living, they have to sell, and it is easier to sell to someone when they know what he wants. The gem dealer is your connection to the huge world of gemstone suppliers. He goes out and sometimes travels to the ends of the world to buy what he thinks he can sell. When you establish this relationship with him, then he has a better idea what you, his customer, want. If, on the other hand, you want to save money and use your new-found skills, buy from the bulk pile and see if you can find an unclaimed treasure.

There is an old saying about buying gemstones and jewelry that still holds true. "Buy from someone you know and trust." There is a purpose to joining a lapidary club; people there already know someone they all trust. Lapidary clubs all have shows, and within these clubs are members who have been dealers for many years. There is a family that are members of the San Diego Lapidary Society and the San Diego Gemological Society whose lifetime business has been supplying members of these clubs with everything they need. From aprons to goggles, faceted rough to mineral specimens, they have had it all. They have since retired from most shows, but their son, Thomas Schneider of Schneider's Gemstones in San Diego, carries on the name selling gemstones and faceting and cabbing rough in the jewelry building on Fifth Street. Thomas doesn't attend the club shows like his parents, but caters to high-end sapphire and ruby jewelry designers and rare gemstone collectors on the West Coast.

If there is a particular piece of rare and unusual piece of rough you want, Tom's Web site, www.TMSgems.com, carries it. Tom's feelings about enhancement are: "It is very important... a necessity... to be honest with all your buyers, and disclosure is required for all the big dealers." Tom has a list on his display cases that describes which stones are enhanced, typically enhanced, or not enhanced. Another big dealer of gem rough in San Diego is Mark Kaufman. Both of these dealers are honest, experienced with gem rough, selling, and willing to share what they know. I am not saying that gem and jewelry show dealers are not honest, or that you won't find a good deal at club shows. What I am saying is leave your pocketbook and wallet at home or in the car until you understand what you are looking at.

continued on next page

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Gemology: Learning the Craft *from page 61*

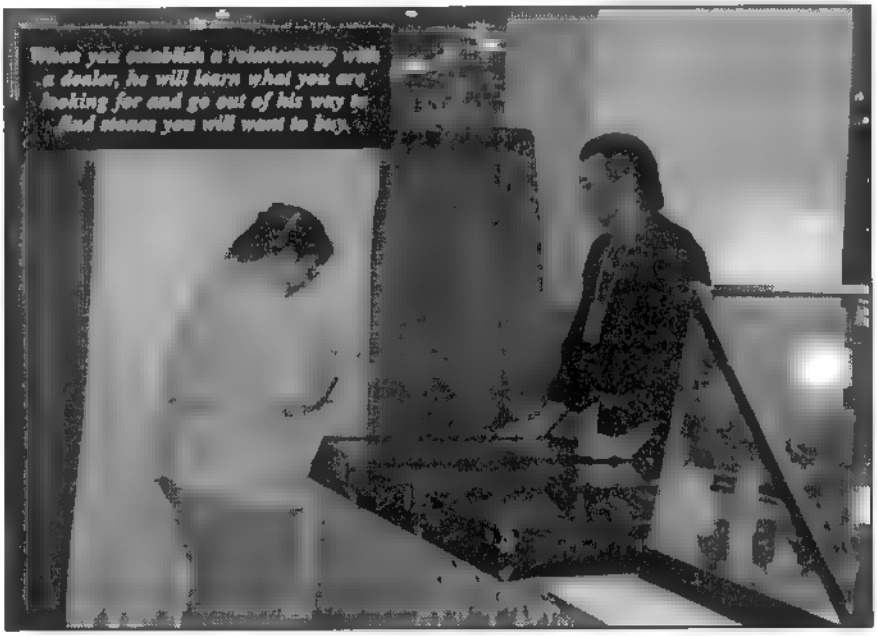
It is important to know that enhancements usually begin when the stone is pulled out of the ground by the miners. When blue sapphires and rubies are pulled from the mines, they are normally heat treated before they are sold. Over 90 percent of all sapphires have been heat treated. How can you determine whether a stone has been heat treated? For a gemologist, it is usually easy to tell by looking at the inclusions under the powerful lens of a microscope. Under the intense heat of the furnace, the gases and liquids will often explode, causing halos to form. If the inclusion is small, you will be able to spot a small halo where there was once a crystal or gas pocket. If the inclusion was big, it will often cause the stone to explode, leaving the miner with many smaller, less valuable stones. So why take the chance of blowing up a stone? Heat treating at extremely high temperatures will cause the silk, usually titanium, to reform back into the stone, leaving a crystal-clear stone. A smaller, highly transparent, colored stone is much more valuable than a milky-colored, zoned stone. This is a job for a trained gemologist in determining the value of a gemstone.

Those who wish to gain the most from these lessons should also spend the time learning the proper names of the stones, which groups they belong in, and when to use their incorrect names, or what I like to call their "rockhound names." As you walk down the aisles of the gem shows, you will see similar stones with different names. It is not important to try and memorize the names, repetition and practice leads to speed and accuracy. It is useful to carry a gem identification book with you when you go to any of these shows. Look up in your book the names the person is giving you, this more important than sitting down in your living room and memorizing the stones. A good book to carry is *Gemstones of North America*, by John Sinkankas. When you are walking around the shows, you will find at least one person selling mineral and gem identification books. Buy the one with the most pictures and identification nomenclature. Don't worry if you don't understand what the characteristics mean, we will learn this as we go along.

Species and Variety

Species is a division of minerals that have, in general, the same physical, chemical and crystal structure and optical characteristics. The members of a species must have the same refractive index and specific gravity. Yet, they may vary widely in color, clarity and name. In previous articles, we learned how to use the refractometer and its importance to the gemologist. I explained how the gemologist's most important tool was used in the detection and separation of gemstones. Everyone has heard of rubies and sapphires, although not many people understand that they are the same species, corundum (kor RUN dum). Both have a hexagonal (trigonal) crystal system and a chemical composition of AL_2O_3, but they are different varieties. It is not uncommon to find multicolored "sapphire" jewelry available at high end jewelry shows. The difference in color is caused by slight differences in chemical composition and not coloration added during enhancement.

While we are on the subject of corundum, it is important that you get a brief explanation about enhancements. There is more to the gemologist job than just read-


When you establish a relationship with a dealer, he will learn what you are looking for and go out of his way to find stones you will want to buy.

ing the numbers, and corundum, or rubies and blue sapphires, are the most valuable colored gemstones sold today, and probably the most imitated and enhanced.

As I described, species must have the same physical, chemical and optical characteristics. Rubies and sapphires are two varieties of the mineral species corundum, so the refractometer will only tell you that your stone has a refractive index (RI) of 1.76. If you have a good set of heavy liquids or an accurate scale and perform the hydrostatic method, the specific gravity (SG) will be 4.0. If the stone is red or dark purple, it could also be a member of the garnet family, rhodolite, which has a slightly lower SG, but is close enough to be mistaken for corundum if you're not accurate or if you are using a heavy liquid set common to most gem labs. Garnets are neither heat treated nor enhanced, while sapphires are commonly enhanced. A pink, double refractive stone can be positively identified as a corundum.

Now, what is it worth? Here's a hint. Natural, untreated gemstone is worth more than a treated, enhanced stone. So what is an enhanced stoned worth? It depends on a number of factors, but usually you can determine the price of the material by how expensive the rough is. This is why I suggest you join gem clubs and go out and dig for the material yourself. The mineral species quartz -chemical composition SiO_2, hexagonal (trigonal) crystal system— is probably the most common mineral found on earth. Rubies and sapphires, however, are usually found in alluvial deposits, or riverbeds, in only a few locations in the world. Quartz has been regarded as one of the most revered gemstones through out history and is commonly enhanced. The difference in price between an enhanced quartz stone and a natural quartz stone isn't much, but the difference between a natural and an enhanced sapphire might be hundreds of dollars. Quartz is a mass-produced (manmade) commodity and produced at levels higher than even corundum. Both stones are commonly used in the watch production industry and related jewelry trades.

The biggest difference seen today is in color-enhanced diamonds, a natural red diamond sells for close to $1 million per carat (only four are known to exist in the world), while color-enhanced red diamonds sell for a few thousand a carat. Topaz is another stone that is typically color enhanced. Topaz can be found in various colors, but is commonly sold in deep blue and red. Both of these colors can add 500 percent or more to the price of the finished stone.

Enhancement

Now I want to touch on the legality of

Anyone contemplating the purchase of this nice red coral and silver necklace should ask the seller whether the stones are natural or treated. Natural coral costs five to 10 times more than enhanced coral, but looking at the case you can't tell the difference.

enhancement and the gem trade. Last year, I wrote an article on the detection of enhancement, the demand for disclosure by the buying public, and the responsibility gem dealers must assume (March 2002 *Rock & Gem*, page 60). The Federal Trade Commission (FTC) was established in 1915 to help enforce the antitrust laws. Times have changed, and the FTC now spends a great deal of time and money on its Bureau of Consumer Protection, which is set up to protect the consumer against misrepresentation and deceptive advertising and marketing practices (see www.ftc.gov). The majority of consumer protection has evolved throughout the years as the agency's definition of unfair and deceptive practices has been tested in the marketplace. Congress amended Section 5 of the original FTC Act in 1930 to say "unfair and deceptive acts or practices in or affecting commerce are hereby declared unlawful." In everyday words, Congress orders the FTC to fight "unfair and deceptive acts or practices." The wording handed down by Congress lacks clear definition, this is done on purpose, as it gives the FTC leeway as to what advertising is deceptive and what market practices are illegal. The FTC staff consists of five commissioners who decide by a majority vote whether a suspected practice is unfair and deceptive. The key term is deceptive. The good news is that the FTC has a three part test for guidance in defining deception.

1. There is a misrepresentation or omission of information in a communication to consumers.
2. The deception is likely to mislead a reasonable consumer.
3. The deception is material, that is, it is likely to be misleading to the detriment (money out of your pocket) of consumers.

Some clarifying words about deception. First, not all omissions are deceptive. Omission of information is not deceptive if there is no misrepresentation or practice that takes advantage of the consumer. Second, in deciding whether a practice or omission is deceptive, the FTC at how it is presented to the consumer. They look at the whole ad or practice to see what the consumer thinks when they see it. Third, a reasonable consumer is an average person on whom the marketer is focusing his attention. Fourth, the representation or omission will most likely affect the way the consumer sees the product. Fifth, no proof of injury or loss of money is necessary to prove misrepresentation or deception, but it is usually what precedes a complaint. The FTC considers these factors in determining the basis.

1. The product
2. The type of claim
3. The consequences of a false claim and the benefits of a truthful claim
4. The cost of developing substantiation for the claim
5. The amount of substantiation that experts believe is reasonable

This is a word of caution to those first-time shoppers, many dealers will only answer your questions about enhancement if you ask them. Since you are new to this environment, you will not know what to ask, and can find yourself buying what looks like a high-quality gemstone at a great, low price. Only later will you discover it is an inexpensive stone that has been altered and that you paid too much for a very low-quality stone or piece of jewelry.

FIELD TRIP

IRON HILL HEMATITE

This Obscure Site Offers Great Collecting

by Robert Beard

Most mineral collecting areas in New Mexico are well known and have been collected for decades. However, as in most big states, as you scour the literature for collecting sites, you keep turning up more that warrant a closer look. A field trip log in an old geological society guidebook, a site description in a self-published rockhound guide, or an obscure reference in an old state survey publication can all lead to good sites. When you can find them, you may find they have not been subjected to as much collecting as the better known locations.

An obscure site that offers great collecting for hematite is the Iron Hill District in the southwestern Robledo Mountains of New Mexico. This site is unique because the mineralization is all botryoidal and reniform hematite, and similar hematite mineralization of this abundance does not—at least to my knowledge—occur elsewhere in New Mexico. The hematite is said to be similar to that found in the West Cumberland and the Forest of Dean deposits of England, which are famous for their "kidney ore" specimens.

HEMATITE THROUGHOUT HISTORY

I first learned of the Iron Hill District from "The Geology of the Organ Mountains, New Mexico," by Kingsley Charles Dunham, which is available as Bulletin 11, Part III, from the New Mexico Bureau of Geology and Mineral Resources in Socorro (505 835 5425). This work was first published in 1935, and was reprinted in 1980. Part III of the publication covered the mines and mineral resources of Dona Ana County, and is an extremely useful text for anyone involved in mineral collecting in southern New Mexico.

I had this publication for years, and thought that I had read everything in the book many times over. However, in December 2001, when planning field trips in the region, I came across the reference to the Iron Hill District. I had never heard of the place, and I noted that Bulletin 11 described the hematite as "coarse dark red botryoidal masses made up of radiating fibers." This description indicated that the deposit was unique and likely worth checking out.

Hematite is one of the oldest known and most important minerals. Ancient man may have first noticed hematite because of its deep red color. Powered hematite could be used for red paint, and this likely was its original use. The first person to pick up a piece of hematite may have also realized that it was much heavier than other rocks. Other iron minerals, such as magnetite, were likely also noticed at that time.

The earliest documented use of iron was around 2000 BC, when Egyptians used meteoric iron in their weapons. Specularite, which is a platy, metallic hematite that resembles native metal, may have also clued the ancients into the potential for making iron from hematite.

However, making iron out of hematite is a lot more difficult than making copper from native copper ore. Native copper could be hammered into shape and melted at relatively low temperatures, but hematite had to be smelted at much higher temperatures in a furnace. It is not certain how this was first discovered, but someone figured how to obtain another useful metal by putting those heavy red rocks in a fire.

The Iron Age began about 1000 BC, and by 400 BC iron use was common. By the time of the Middle Ages, iron making was known in all parts of the world except for what became the Americas. Ironically (no pun intended), though the native peoples of the New World had many iron deposits, their lack of iron making capability sealed their doom. Weapons of wood, bone and stone were no match for iron and steel.

continued on next page

Hematite is one of the oldest known and most important minerals.

Iron Hill Hematite *from page 65*

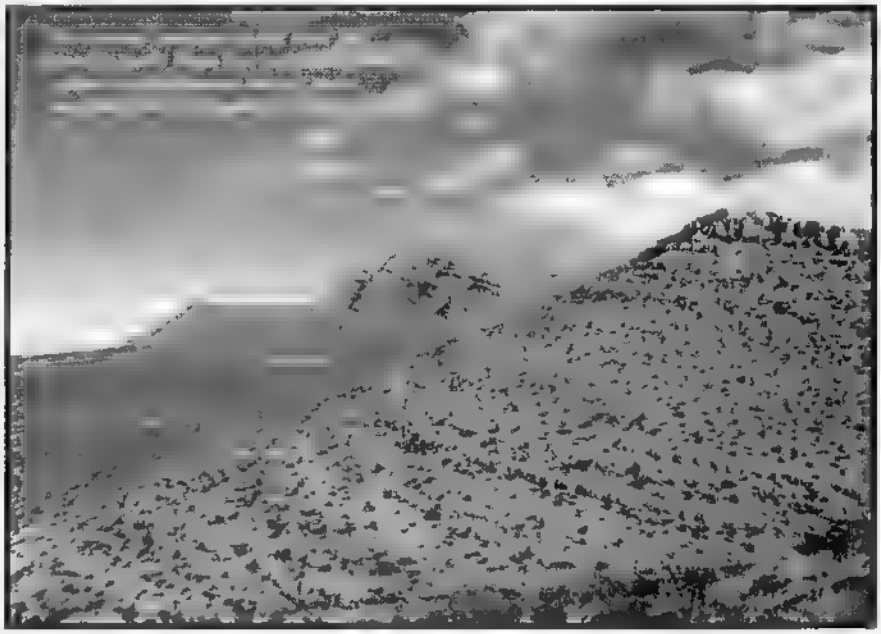
In the early days of iron manufacturing, the iron works were located near the iron source. Iron making required iron ore, fuel for smelting, and limestone. Charcoal, which was made from burning wood, was the typical fuel source. Many small furnaces were constructed throughout iron producing regions during the 1700s and the ores were mainly bog iron that could be easily mined on the surface. The process was labor intensive and could only produce small amounts of iron but it worked. However, the demand for wood for producing charcoal stripped the forests and charcoal took time and additional labor to produce.

As the Industrial Revolution accelerated in the early 1800s, several new discoveries and techniques had a profound effect on iron. The great iron ore deposits of the Lake Superior District were discovered in 1844, and around 1850 smelters began to use coal instead of charcoal. This made the furnaces more efficient and allowed wood to be put to more productive uses such as house and mine timbers.

As America expanded and the European countries industrialized further, the demand for iron and steel grew. The amount of fuel needed to manufacture steel was tremendous, and steel producers soon found in many cases it was more economical to bring the iron ore to the fuel source. The fuel sources were also generally much closer to the end users of the steel in the population centers. This is the main reason Pittsburgh became a center for steel manufacturing, although it did not have any nearby major iron mines. It had vast resources of bituminous coal and access to markets and became one of great industrial centers of America during the mid-20th century.

Iron ores are relatively common in the United States. Iron has been mined in most states but consolidation and economies of scale have made virtually all the smaller deposits uneconomic. Today, most raw iron ore in the United States is produced in the Lake Superior iron districts. Foreign sources of iron ore and steel further strain the competitiveness of American steel. Many companies have recently gone bankrupt and have shut down completely, and the great steel mills of Pittsburgh are virtually gone. Some of the few successful steel companies today such as Nucor, produce steel from mills that process exclusively recycled steel. While steel is still an integral part of the world economy, the industry is vastly different in the 21st century.

The Iron Hill District deposits were mined sometime before 1935, which was the original date of Dunham's publication on the district. No further information could be found on the exact dates of production from the district. Dunham indicated that the deposit could not be mined economically, given its remoteness and distance to markets. Since the Iron Hill deposits were so hard to get to and so far from the end users, it is highly unlikely that the deposits could ever have become profitable even in the boom years of the American steel industry.



According to Dunham, the hematite bodies replace sections of Pennsylvanian age limestone of the Magdalena Series. However, Dunham wrote his text in 1935, and the term "Magdalena Series" has long since fallen out of favor with stratigraphers in New Mexico. It was used for so many different regions and formations that it became useless. Interestingly, the name would imply that the rocks that best represent the Magdalena Series are in the Magdalena Mountains in southwest New Mexico. The rocks that best represent a particular rock formation are often referred to as the "Type Section." However, as anyone who has visited the Magdalenas may recall, the limestones in the Magdalenas are highly faulted, intruded, and metamorphosed, and are the last place to pick for a type section.

In the November 2001 issue of *New Mexico Geology* published by the New Mexico Bureau of Geology and Mineral Resources, Barry Kues described the Pennsylvanian system in New Mexico in detail in his article "The Pennsylvanian System in New Mexico overview with suggestions for revision of stratigraphic nomenclature." Kues indicated that there is little published, detailed information on the Pennsylvanian system of the Robledo Mountains. The Pennsylvanian in the Robledos has been assigned to the Madera Group which reflects deposition on shelf and basin margin and in slowly subsiding basin conditions. The Pennsylvanian rocks exposed in the Robledo Mountains were deposited on the Robledo Shelf along the western side of the Orogrande Basin. It is somewhat surprising that so little work has been done in the Robledos, given their proximity to the relatively large cities of Las Cruces, New Mexico, and El Paso, Texas, both of which have universities with excellent geology departments.

The host limestones of the hematite ores dip to the southeast about 20 degrees. According to Dunham, the ore bodies are lenticular, and appear to be related to fissure zones that cut across the bedding of the limestone in various directions. Sixteen bodies of hematite have been opened up, and many outcrops have not been explored. Fourteen short tunnels are reported to be in the hills, and there are many shallow shafts. The dimensions of the bodies vary from small masses to large bodies up to 200 feet long, 120 feet wide, and unknown vertical extent. Dunham indicated that a moderate resource of iron was available, but the remoteness of the deposits and their distance to markets made them uneconomic to mine.

As mentioned earlier, the deposits are reported to be mineralogically similar to the hematite deposits of West Cumberland and the Forest of Dean, England, which are known for "kidney ore" hematite. These deposits formed in Carboniferous-age limestones that were formerly overlain by a great thickness of Permian "red bed" deposits, and the Iron Hill District is similar in this respect. The

continued on page 68

Permian Period began after the close of the Pennsylvanian Period, and the Pennsylvanian Period in America and the Carboniferous Period in Europe are generally considered to represent equivalent times. The red beds are generally considered to be indicative of increasingly arid conditions in the Permian. The Permian red beds may have provided the hematite cement that leached and subsequently precipitated into the underlying limestones, and this resulted in the formation of hematite.

This seems like an obvious explanation when you think about it. New Mexico is well known for its Permian "red bed" deposits. The Abo Formation, which is mainly sandstone, is one of the best known of the red beds in New Mexico. It is a prominent red-brown, indicating that it is rich in hematite. It is extensively exposed throughout New Mexico, and one can easily imagine rainwater percolating through cracks in the Abo Formation and leaching iron into the underlying Madera Group limestone, which precipitated as hematite.

One important detail, however, is left out. Why is this type of hematite found only found in New Mexico in the Iron Hill District? I am familiar with most of the mineral localities in the state, and I have never come across any other sites with this type and abundance of botryoidal hematite. If the explanation for the iron is this simple, it should be found in many other places in New Mexico. The lack of similar deposits elsewhere in the state may make the origin for the deposits quite a bit more complex. In any event, the hematite is definitely there.

GETTING TO THE IRON HILL DISTRICT

Dunham's work gives sufficient information to find the Iron Hill District. The district is in the low hills on the western side of the Robledo Mountains, three miles southwest of the western summit. However, Dunham said that the district was "not accessible by road" (not good), and that it is "most readily reached on horseback from the Powell Ranch, seven miles distant." Using my *New Mexico Road & Recreation Atlas* (Benchmark Maps, Berkeley, California), I was able to determine that the district was in the Leasburg, New Mexico, USGS 7.5 Minute quadrangle. This atlas also indicated that the district is apparently on U.S. Bureau of Land Management (BLM) land, which meant it would be open for collecting. Sure enough, in the NW 1/4 of Section 16, Township 22 South, Range 1 West, I saw two adits and four prospects. Based on the information in Bulletin 11, these had to be the Iron Hill District workings. The latitude and longitude of the center of the district is 32° 23' 51"N 106° 57' 00"W.

Most mining districts are accessible by some type of road or trail, as the miners had to get their equipment there somehow. Following roads and trails is often another good way to find mines and prospects, as the old timers did not miss much. However, there are no roads or trails to the Iron Hill District marked on the USGS map. Though Dunham indicated that the district was not accessible by road, the lack of any roads or trails to the mines was quite unusual. This also meant that it would likely be impossible to drive to the workings.

I had recently purchased a very useful reference, *The Roads of New Mexico* (Shearer Publishing, Fredericksburg, Texas). This book, available in most area convenience stores that sell maps, showed there was a road west of the district that passed the area in a north-south direction. It appeared to be a good road, which was important since I only had to small two-wheel-drive vehicle this trip. However, I would have to stop at precisely the right spot and hike approximately two miles over flat terrain to get to the mines.

I visited the district in late December 2001. Winter is one the best times to visit the mountains in southwest New Mexico, as it is generally warm in the afternoons and you do not have to deal with the summer storms of the monsoon season in July and August. The roads were no problem. A key landmark, which is shown on the Leasburg quadrangle in the SW 1/4 of Section 19, T22S, R1W, is a dry lake bed and windmill that you have to drive past. About 1.5 miles past the windmill, I stopped my car and began the overland trek to the district. I left a note on my windshield saying who I was and where I went.

The hike was relatively easy, but I had to cross several small arroyos. A few cattle were in the area also, but they did not cause any problems. I was able to walk in nearly a straight line to the hills. It is very easy place to keep your bearings. I did not see any indications of posted land or other indications that one could not hike over the ground.

As soon as I neared the hills, I was able to spot the southernmost workings. I did not see any posts indicating that the ground was claimed. The dumps are easy to see, as they are light red against gray limestone. I climbed up the dump and checked out the exterior of the workings, which were a short adit that was open to the sky a few feet from the portal. Although it was short, I did not dare go through the portal. The dump near the portal was loaded with red hematite, much of which had a bubbly appearance that resembled goethite. Breaking pieces apart with my hammer revealed that the bumpy hematite pieces consisted of radiating crystals. Many pieces also had limonite, calcite and gypsum.

After I was done at this mine, I worked my way to the other workings to the north. The mineralization was similar, but I thought it was much more pronounced in these workings. I was able to find several pieces with nice botryoidal features but several of them were weathered, and some the hematite had turned from dark red to bright orange.

Some of the pieces were a shiny gunmetal gray and resembled pieces of steel. The sections underneath the botryoidal pieces often appeared spongy, and resembled cinders or scoria. If I found similar material back east, I would have sworn it was slag. There were no indications of any furnaces nearby the mines, much less any fuel to operate a furnace, so I am reasonably certain that none of the material I saw was slag.

There is a virtually unlimited amount of material on the dumps. A hammer is needed to break off and trim the best pieces. I especially liked the pieces that had large, round, smooth sections that were more than 1 inch in diameter. Many of the other pieces are agglomerations of smaller balls of hematite, and I did not think these were as interesting as the pieces with the larger spherical sections.

I soon had picked out the pieces that I wanted to take. In addition to being limited by the size of my pack, I also had to take the material back to Pennsylvania on a plane, so I made a real effort to take only the best pieces. I spent considerable time trimming them down. It took only about an hour to walk back to the car.

The Iron Hill District is well worth visiting if you have the opportunity. However, it is only for the adventurous type, and I do not recommend visiting it with young kids or cranky spouses, since you have to hike a couple miles. I also do not recommend it for afternoon summer trips, since if a lightning storm kicks up, there is no place to hide in the low hills or the broad valley. Late fall, spring and winter are the best times to visit. However, if you travel in the morning during the summer, you should not have a problem, as most of the thunderstorms occur in the afternoon. The remoteness of this district, coupled with the fact that it is virtually unreported in most of the mineral guides to the area, make it one of the few districts in New Mexico that has not seen many collectors. ♦

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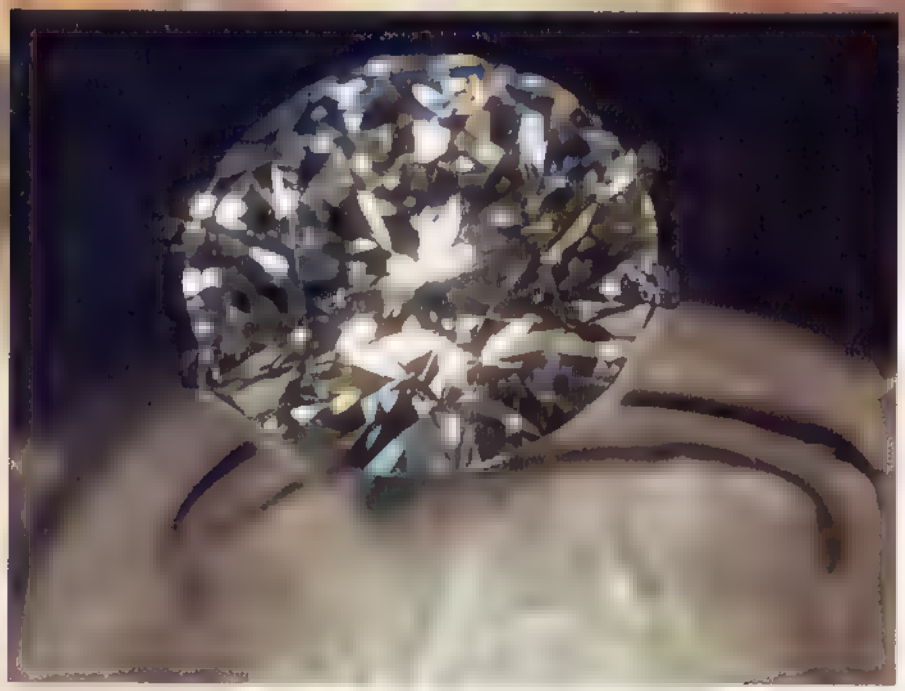
MINERAL HARDNESS ACCORDING TO MR. MOHS

Part II: Apatite through Diamond



This choice 5-carat diamond is a lovely example of the hardest of Mother Earth's minerals, number 10 on the Mohs scale (Photos by the author)

by Bob Jones

In Part I of this discussion of the Mohs hardness scale, I described the background of the scientist who developed this useful identifying technique while pointing out some of the pitfalls in depending on it too much. I also treated the first four minerals on his scale: talc, gypsum, calcite and fluorite. In this second part, I will describe apatite, orthoclase feldspar, quartz, topaz, corundum and diamond. These six minerals are not only the harder members of the Mohs list, but they also range from semiprecious to precious gems as they have

Perfectly sceptered, these quartz crystals are typical examples of this hardness 7 mineral.

Two examples of corundum, red ruby and pale yellow sapphire, both have a Mohs hardness of 9.

Apatite, like these crystals from the type locality at Ehrenfriedersdorf, Germany, was Mohs' choice for his hardness 5 mineral.

one of the most important properties necessary for a durable gem, hardness. The argument can be made that calcite and fluorite are often faceted as gems, but they are hardly durable.

Be reminded that all the minerals on the Mohs list do vary ever so slightly in hardness, so they are only useful guides a collector can use to help arrive at a tentative identification. This suggests that care must be taken not only when doing a hardness test, but also in the selection and application of the testing specimen.

When Friedrich Mohs developed his scale in the early 1800s, he had to choose quite common, as well as predictably consistent, hardness minerals. Of course, when you get into the really hard minerals, corundum and diamond, his choices were severely limited. Nothing is as hard as diamond, so its choice was obvious. And the corundums had to become number 9 simply because of their gem qualities, extreme hardness, and relative abundance.

All the textbooks list apatite as a mineral, but when you turn to the given page, you find the word "group" after the mineral name. That's because apatite is one of the more promiscuous chemical compounds. While modern textbooks show the apatite group to include fluorapatite and chlorapatite, older texts list a veritable menagerie of apatite based species, including strontianapatite, hydroxyapatite and manganapatite. Add to that a half dozen or more subspecies names, and you've got real confusion. Scientists went to work to identify the true members of the apatite group and came up with fluorapatite and chlorapatite. All the others are simply varieties of these two major species.

continued on next page

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Mineral Hardness According to Mr. Mohs *from page 73*

My introduction to the apatite group came when I was working on my master's thesis in Connecticut. The subject was "Luminescent Minerals of Connecticut", the thesis was later privately published. It was common knowledge that the Connecticut pegmatites offered an abundance of apatite rich in manganese, which caused it to fluoresce a very lovely yellow-orange with short wave excitation.

The apatite group is basically a calcium/fluorine compound with more calcium and the phosphate radical. The initial calcium and fluorine can substitute for each other equally hence, the two members of the group. The other varieties, like manganapatite, result from the so-named metal manganese, or strontium, or the hydroxyl radical, squeezing into the structure, replacing calcium or fluorine. This causes the problem of distortion in the internal structure, affecting the properties, including the hardness, which is supposed to be Mohs 5.

Gemmy apatite is fairly common and can be faceted, though it barely qualifies as a gem because it is almost too soft to be worn in any form. It has to be mounted in a protecting bezel or shadowbox and never in a ring. Fluorapatite is the most common and certainly prettiest member of the group. The royal purple fluorapatites from Mount Apatite in the Androscoggin County, Maine, pegmatites are truly magnificent. They are bright, gemmy, sharply hexagonal, richly colored, and unfortunately, uncommon. Pale violet apatites are also found in Europe, but are a mere shadow of those from Maine. However, perhaps the most stunning violet-colored apatites were found with byssolite and superb epidotes at the famous Austrian locality Untersulzbachthal. They were sometimes found as lovely, tabular, hexagonal discs of light violet color and superb crystal form. The great tin mines at Llallagua, Bolivia, have produced wonderful pink fluorescing apatites of a similar disc form.

The largest apatites again fluorapatites, have come from several places in Canada. Here they are found in a metamorphosed calcite rock of pink to orange color. The apatite crystals are doubly terminated and a dark green to green-brown color. They can reach 50 pounds in weight, and foot-long crystals are fairly common. The problem with these apatites is that they are not transparent, they are nearly opaque, in fact, and tend to fall apart when chiseled out of the calcite. After all, if you were subjected to the deep frost that occurs at Otter Lake, Ontario, you'd come apart on exposure, too.

My favorite locality for collecting apatite is in Mexico at Cerro de Mercado, Durango. A huge mountain of iron ore juts from the desert floor and produces lovely limonite pseudomorphs after hematite and literally millions of gemmy yellow fluorapatite crystals. The reason I like collecting there is because the crystals are all over the place in the soil, in the road gravels, on the dumps, and of course, in the ore. Blasting destroys too many of these yellow gems, but nice singles almost never on matrix, are easily obtained. These lovely hexagons make fine testing crystals.

Hardness 6 on the Mohs scale is represented by orthoclase feldspar, one of the most common minerals on Earth. It is found in most granites and a dozen other rock types, and is often seen as sharp single crystals, phenocrysts, in a host rock. These sometimes weather out as nice singles.

There are actually six members of the feldspar group, which are divided into two subgroups: the potassium feldspars, dominated by orthoclase, and the sodium-calcium group, which includes albite.

When working with orthoclase as a testing mineral, you have to be sure first of all that you are using orthoclase and not another type of feldspar. Second, feldspar tends to weather easily, so the crystal you use has to be fresh and sharp. The weathering of feldspar is what produces its most important industrial product, clay. Most clay is pretty useless and is, in fact, a real nuisance, but good clay has lots of uses. The making of bricks is one, but pottery is historically the most important use.

Using available clay, prehistoric ancients made useful pots to hold all sorts of important things, food in particular, and later, water and oil. Perhaps clay's most important indirect role was in the accidental discovery of metal smelting. As potters learned to fire their clay product to make it much more durable and somewhat waterproof, they also realized they could use powdered minerals to put colored designs on their pots. This practice later helped archeologists identify groups of people long since vanished.

The addition of metallic minerals—most particularly copper oxide and later iron oxide—to color pots being fired in a kiln caused the copper oxide to break down, releasing the red metal copper. This was the accidental discovery of metal smelting! Consider what this did for the progress of humankind. Continued experimentation refined what had been discovered accidentally, thanks to lowly feldspar clay!

Another very important use for orthoclase feldspar clay is in making the finest delicate porcelain. Both French and English fine porcelain. Wedgewood is one example—used the finest snow white orthoclase clay. Wedgewood's clay came primarily from the famous clay pits of Cornwall, England, where the outcropping granites had been exposed to the quite severe weather of the area for centuries. This weathering produced some of the finest pure feldspar clay found anywhere.

Orthoclase is also a collector mineral. The finest crystals are found on the Island of Madagascar. Lovely, bright yellow, gemmy crystals, usually as single prisms, from the island bring high prices, as they are exceptionally fine and rare. The Swiss Alps produce choice, white, sharp crystals of adularia, a variety of orthoclase. Often found with green chlorite and usually twinned, these crystals are classics in the truest sense. In rare cases, they are also found associated with small, fine, gemmy yellow fluorapatites here.

Yet another member of the potassium feldspar group is moonstone, a very beautiful opalescent stone that occurs in the gravels of Sri Lanka as a fine gem. Albite, a sodium feldspar, can also be found in a lamellar twinning form that has a distinct silvery, shimmery effect, so it is also given the name moonstone.

What can be said about quartz, the mineral chosen by Mohs for hardness 7? Where would the lapidary be without this ubiquitous gem? Where would the mineral collector be without the many varieties of quartz that offer a sack full of massive gems and superb crystals ranging from micromounts to the giants of the museum world? Without quartz, the world as we know it would not be the same. It is the main ingredient in glass. When you get up in the morning, a quartz mirror shows you as you really are. It is prevalent in the optical world, which includes the huge mirrors used in the finest and largest optical telescopes in the world. Much of our food is packed and preserved in glass. Imagine the added difficulty to families if they did not have glass containers in which to preserve food for the long winter months. I can recall my mother preparing and canning virtually everything we grew on the farm, and stacking shelf after shelf with jars of vegetables and fruit for the winter. Thank goodness for glass! Thank goodness for quartz, the natural silicon dioxide that is the main ingredient in glass making. And as an aside, where would Florida and California be if there was no quartz beach sand?

Be that as it may, like other members of the Mohs scale, quartz has a variable hardness that may be just below or above 7. When using quartz to test other minerals, be sure to use the termination point of a rock crystal. The cryptocrystalline varieties like chalcedony and chrysoprase can be slightly less hard than the more or less pure rock crystal.

Quartz is often host to all sorts of impurities; some give it color, while others cause unusual optical effects. When crystallized, the color in quartz, as in amethyst, smoky and citrine, is due to differing electron structures. Most unusual is amethyst, which is quartz that has been irradiated naturally while still in the Earth. Heat it or expose it to intense energy like ultraviolet, and the amethyst loses its violet color. Massive forms of quartz, on the other hand, owe their color to included impurities. Chrysoprase, for example, has included nickel salts or nickel-rich clay. Again, these do not make for good testing instruments.

As a science teacher, I used to play little "tricks" on students to make a point. For example, I would bring a rather large doubly terminated quartz crystal into class.

Topaz, hardness 8, is the first truly precious gem on the Mohs scale. (Image courtesy WWW.THAIGEM.COM)

Someone would invariably ask if it was a diamond, and my answer, instead of lying, would be a knowing smile implying that I was holding a very valuable gem. This was met with considerable disbelief, so we would pursue a discussion on a test for a diamond. Almost immediately, someone would announce that diamond will scratch glass. Of course it will. So, I would use my quartz crystal to drag a large scratch on a classroom window, and that would recruit a number of believers. Of course, any good rockhound knows that quartz can scratch glass and any mineral can scratch itself, albeit with difficulty. Since common sand and even much dust is basically quartz, jewelry made from any mineral with hardness 7 or less can suffer from coming in contact with them.

For the lapidary, the variation in hardness of the massive quartz varieties is well known, since they have all experienced undercutting in their work. This is a good example of the effect of impurities in quartz, as well as the vagaries of the quartz itself. And every lapidary knows that cleanliness is next to godliness in caring for your equipment.

You may wonder why Mohs chose topaz instead of garnet for hardness 8 on his scale. After all, garnet is harder than quartz. But, garnet comes in several varieties and they do differ markedly in their hardness. Grossular, for example, barely outdoes quartz in hardness, being a hard 7. Pyrope, often found as a gemmy red stone, is usually Mohs 7.5. So Mohs went to topaz, even though it has perfect cleavage and does vary ever so slightly in hardness because of this.

While calcite, fluorite, apatite, feldspar and quartz are all useful as gems, they are really semiprecious. Topaz is the first truly precious gem of the Mohs scale. It can be faceted and worn openly, as it is unaffected by quartz or the vast majority of substances it might come in contact with when being worn. It comes in a variety of colors, the most spectacular being the peach, pink and orange topazes best known from Brazil. The more common color for topaz is blue, ranging from very pale to fine sky blue. Choice yellow topaz comes from Europe, while the best source for blue crystals was Russia in Mohs' lifetime. Later, fine topaz was found here in America—in Colorado, Texas and elsewhere—but never in the quantity seen from Russia or Brazil.

Except for diamond, the hardest gems in common use are the two very colorful and very popular members of the corundum group, ruby and sapphire. They are capable of scratching the beryl minerals like emerald (Mohs 7.5 to 8) and morganite, also close to Mohs 8. They scratch topaz easily and can even scratch the gem chrysoberyl, which boasts a hardness of 8.5! Of course, in a hardness kit, the corundum you get is not a red or colored gem. It is a slightly impure and nongemmy corundum crystal. Still, the hardness is sufficient to serve you well. Fine, gemmy, red rubies and sapphires, which can match any color of the rainbow, are greatly desired and sought. But the rubies I like the best are from Africa, those huge red crystals found embedded in bright green zoisite. What marvelous carving material these two contrasting minerals make. Only really skilled carvers can work this lovely combination of a softer green gem and the very hard red gem with success. Some of the finest gem carvings I've ever seen were done in this red/green ruby/zoisite rock.

continued on next page

Not all rubies are beyond the pocketbook of the average rockhound. From Mysore, India, nice red hexagonal crystals can be had at reasonable prices. They are not gemmy, but they are just as hard and maybe more useful!

Certainly the most unusual story I have ever head about rubies from India was told to me by a fellow we interviewed when I was working on the Smithsonian video "Gemstones of America." It seems this fellow had joined the Hare Krishna movement and became so learned that he was sent to England to proselytize. There he met the music group the Beatles and taught them his beliefs. Later, he went to India for further training.

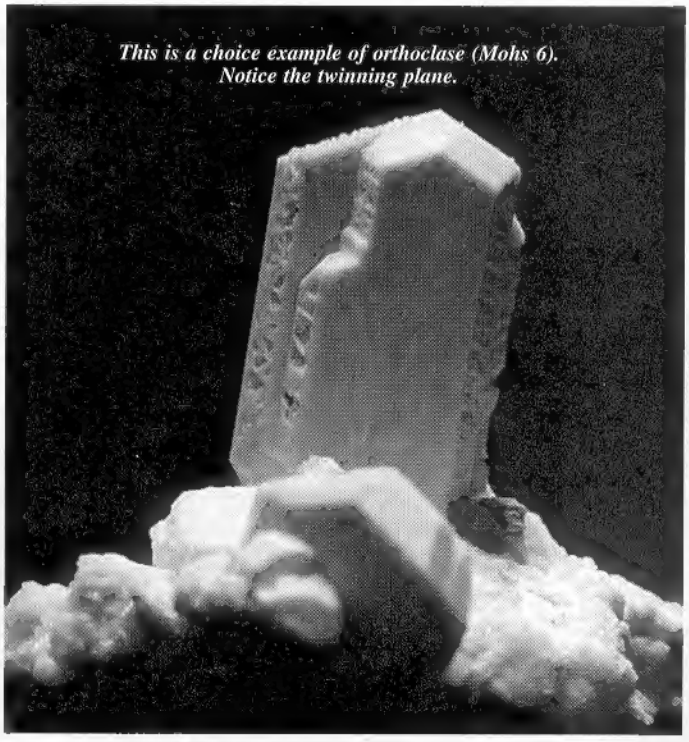
While there, he stumbled on a ruby deposit. Torn between his beliefs and potential wealth, he chose the rubies but needed money to develop a mine. So he contacted his old Beatle buddy George Harrison, who lent him the wherewithal to get things going. Instead of repaying Harrison with money, he shipped his benefactor a huge load of red ruby crystals—nongem, I assume. So what did Harrison do with all these little red beauties? He paved his pool deck with them! That I would love to see!

All of which brings us to that gem of gems, Mohs hardness 10—diamond! I have yet to see a hardness testing kit sporting a diamond. Theoretically, diamond is pure carbon, but is seldom found as such in nature. There is another pure carbon mineral we call graphite, since one of its uses is as a writing material. Graphite is exceptionally soft due to very poor bonding in its structure. It forms hexagonal crystals, while diamond crystals form in the isometric or cubic system.

Diamond's hardness is due to exceptional cohesion within its atomic structure. The carbon atoms in diamond share electrons with each other to form very powerful covalent bonds, which are very resistant to separation. Graphite, on the other hand, has extremely weak bonding, so it cleaves readily. It may surprise you that diamonds also cleave perfectly along the octahedral plane, just like fluorite, though I doubt old diamond miners sit on their porch with a razor blade, cleaving chunks of diamond as did fluorite miners in the Cave-in-Rocks, Illinois, region to make saleable specimens.

Diamond is so hard that only another diamond can scratch it. George Harlow compares its hardness to that of the other members of the Mohs hardness scale. The difference between diamond (10) and corundum (9) is greater by far than the difference between talc (1) and corundum. Harlow's excellent book *The Nature of Diamonds* is full of fascinating scientific information about this hardest of earthly substances.

Just like other members of the Mohs scale, diamond's hardness varies depending on where you attempt to scratch it. The cube face is not quite as hard as the octahedral face. And, not surprisingly, diamonds tend to form octahedrons to a much greater extent than cubes. When working a diamond, a faceter will try to attack the gem on the slightly softer cube face if possible.



This is a choice example of orthoclase (Mohs 6). Notice the twinning plane.

One of the fallacies about diamonds is that they are rare. They are far from rare. For example, deep under the Kremlin's Armory Museum in Moscow, there is a huge room stacked high with uncut diamonds mined from Siberia since the 1950s. Production of diamonds in one year is well over a half *billion* stones. True, most are industrial grade rather than gem grade and most are under a carat in weight, but tight control of the diamond market continues to create the illusion of diamond's "rarity."

There is no information on when diamonds first appeared, but the earliest serious mining of diamonds was probably in India over 2,000 years ago. India was the only source of diamonds until the gem was found in alluvial deposits in Brazil in 1730. Brazil, in turn, was completely overwhelmed by the African discoveries in the last quarter of the 1800s. Africa still holds sway on diamond production, but China, Canada and Australia are also producing. There is even a producing diamond mine in Colorado at Kelsey Lake. The stones I've seen are mostly quite small, but a couple of gems over 28 carats in size have come to grass.

And speaking of coming to grass, almost all diamonds have come to grass from an awful depth. It takes huge amounts of pressure and heat to cause a diamond to develop and those conditions only happen in Earth's upper mantle, below the crust. They reach the crust thanks to magma rock traveling up through crustal weaknesses to come to rest near the surface, later to be exposed by erosion. Since pure diamond is colorless it takes some internal condition or impurity to give diamond such colors as blue, yellow, brown, red, pink, greenish-yellow, and even the rarest colors, violet and orange.

The main impurity in diamonds is nitrogen in one of several forms. The most common colors, like yellow, result from this impurity. Like fluorite, diamond can also suffer what are called color centers. These are actually gaps in the electron structure that affect any light energy that penetrates. One of the more unusual diamonds is the Hope diamond, because of its blue color and red fluorescence. The color is due to the presence of boron as an impurity. Not all diamonds fluoresce, but this unusual luminescent property is now being used as one identifying tool, since the fluorescent or phosphorescent response to ultraviolet light of a given stone is unique to that stone and so it's rather like a fingerprint. Another technique now being used to "fingerprint" the more valuable diamonds is to laser-engrave a registration numbe on the stone that can only be read under magnification.

There you have it. You have to admire Friedrich Mohs for his observational skills in realizing as he worked with minerals that their differences in hardness could be developed into a testing and identification system. His selection of 10 relatively common minerals was nothing short of smart. And though in most cases the individual species vary in hardness within the species, this wasn't known to him in 1822 when he announced his choices. For the amateur field collector, his hardness scale has been a real boon in sorting through Mother Nature's cornucopia of lovely minerals. Developed over 75 years ago, the Mohs hardness scale is still an effect field-testing tool.

by Bob Jones

Happy Accidents

In the April issue of *Rock & Gem*, I mentioned a couple of the accidental happenings in my life that led to some interesting events like ending up on a Discovery channel video. I also mentioned how I got involved in the video "Russian Gem Treasures," again by accident. Several people have since suggested I write about such serendipitous happenings so, on occasion, I'll do just that.

On the subject of videos, my first adventure into video making, which resulted in the Smithsonian tape "Gemstones of America," happened quite by accident. I had a call one day from a fellow named Ray Albrechtson. It seems he had a crew shooting a video out in the field and the script they had received was not acceptable. Ray had called John White, who was boss man of the gem and mineral department at the Smithsonian in those days. After hearing Ray's plight, John suggested he call me to see if I could help. The result was that I wrote a script they could build on and the project continued.

The video involved American gemstone deposits, including Mount Mica, Maine, and Southern California tourmaline, Arizona peridot, and Montana sapphire. I mention these because some pretty interesting stories came out of them.

For instance, at the Montana sapphire dig we met Sam Sperstra, who had been a friend of George Harrison of Beatles fame. It seems Sam had borrowed a lot of money from George to open a ruby mine in India. When it came time to pay Harrison back, Sam decided to do it with rubies. He shipped a couple of tons of rough ruby crystals to England, and George, who wasn't quite sure what to do with them, decided to pave his pool deck with them. So somewhere in England there is a ruby pool deck, and I suspect it will undoubtedly be "mined" by some future rockhound.

As for taping the story of digging tourmalines in Maine, we were able to interview Stan Perham, one of Maine's premier tourmaline experts on that state's most famous gem. Stan told the story of how he discovered the "Jolly Green Giant," a 15-inch watermelon elbaite now on display at the Smithsonian. It seems Stan was digging in a producing gem pocket and the tip of a crystal appeared in the pocket clay. Using a screwdriver (we all know you should never use a screwdriver to dig crystals!) Stan began scratching away the clay. The crystal kept getting bigger and bigger. Stan finally had to pause and catch his breath, as he was hyperventilating from excitement. He finally dug out the beauty—a magnificent gem watermelon tourmaline fully 15 inches long and as thick as your arm—one of the best he had ever found!

The best "Gemstones of America" story happened on the San Carlos Apache Indian reservation in Arizona, where gem peridot is mined by the locals. I had arranged the shoot through a contact I had on the reservation. After a day of filming, we were asked to meet with the Tribal Council. The end result of that meeting was that the council kept the videos to "review" them, promising to return them if they were satisfied with the content. Well, nothing was heard for several weeks. Ray called me and I called my contact, but nothing came of that. Then one day, Ray got a call from some unknown who said the videos could be obtained if an agent for the video company could meet him in a certain café in Globe, Arizona, which is near the Apache Indian Reservation. A sum of money was "requested" for the exchange. So, the meeting was held, the money (payoff) was passed, and the videos were retrieved and used in the final product. Check it out!

Stan Perham (left, in green) is being interviewed for the Smithsonian gemstone video at Mount Mica, Maine. (Photos by the author)

Bill Panczner and I were the first Americans to visit this most amazing gypsum cave at the Buena Tierra Mine in Santa Eulalia, Mexico.

My trip to the chrysoprase mine in Western Australia was another "accident." My friend Randy Polk was always looking for what he called "jelly bean" colors in gems. In fact, he was the first to bring a quantity of purple sugilite into this country from Africa. I met him when I did the first-ever article on the gem in *Rock & Gem*. In his search for bright-colored gem rough, Randy ended up at the chrysoprase mine. While there, he told the owner about my writing, and the owner decided he would like to get some exposure for his new gem property. So, I was contacted and was offered a trip to the mine, at the owner's expense. Let's see! I had to decide if I wanted to go to Australia for free or stay home and work in the yard. That's a no-brainer if I ever heard one.

The trip was 17 days long and we thoroughly enjoyed it. I got to dig chrysoprase and write about it. After a week in Sydney to enjoy that lovely city, we were also given a three-day layover in

Hawaii to "rest up" after our ordeal. The result was a major article introducing the new source for green chrysoprase. The mine owner was happy, as he did very well in Tucson as a result of the article.

The trip to Australia didn't end there. The fact that I did an article that, in effect, promoted a gem material caused yet another dealer to offer me a trip to the emerald mines in Colombia—at his expense, of course. So, off I went to Muzo. What a trip! Muzo is not exactly on the outskirts of Bogata! We had to fly into the jungle in a small plane, landing near Muzo. I found out later that ground control at that airport—actually a single landing strip—consisted of a girl with a walkie-talkie who could tell the pilot when the pigs were off the runway so it was safe to land. She also gassed up outgoing flights by sucking on a hose to siphon gas from a can into the plane's tanks. My concern was that she was chewing gum, and you know gum and carburetors don't get along!

The Jolly Green Giant, a 15-inch watermelon elbaite, was dug by Stan Perham at Mount Mica.

Be that as it may, we had a great time driving through the jungle and visiting the mines around Muzo. I was able to go underground six times, sometimes climbing down a slippery steel ladder for 150 meters or so and sometimes walking straight in. Walking in the mines was always difficult, as the tunnels tended to be maybe 4 feet high, which meant you walked in a stooped position—murder on the legs, as the walk was usually over 1,000 meters! Temperatures in the emerald mines run about 90 degrees and the humidity is 90 percent. The emeralds occur in a filthy black shale, so by the time I finished crawling and climbing in six different mines, I had to toss my clothes away.

In one mine, I was offered a chance to be hoisted out. After a long climb down and an even longer stooped walk to the rock face, being hoisted out, which consisted of sitting in a single rope loop or sling at the end of a single cable, sounded great. Just my luck, the hoist jammed after they got me partway up the shaft. No problem. They jiggled and wiggled the cable while I rocked back and forth but never really banged into the rock walls of the shaft. The gears finally broke loose and they lowered me back into the muck at the bottom of the shaft, and I gladly climbed to grass.

We had a couple of scares while there in Colombia. In one place, I was taking pictures in the town square when the local sheriff came out of his office and yelled to everyone sitting in the square that I was a drug agent taking pictures! My companions immediately hustled me into the truck and off we went at full speed. Another time, I was wandering among some 200 miners and buyers on a day set aside for buying. I had my camera equipment in a bright red bag and I was all over the place documenting what I saw. Somehow the rumor got started that I was a rich gringo with a bag full of cash looking for a good stone. Immediately, my companions shoved me into the truck and we didn't stop driving for several hours. Such is the life of a freelance writer!

Some of the most amazing adventures I have had were in Mexico, a great country loaded with mineral goodies. It all started when my friend Rukin Jelks nominated me to be on the board of directors of the Arizona Sonora Desert Museum, one of the world's great living museums. Rukin, a diligent collector, wanted someone on the board with a love of minerals, since the museum had a really fine mineral collection from the Sonoran Desert region.

Being a part of the museum hierarchy made it possible for me to go on field trips into Mexico, into which country the Sonoran desert extends. So Bill Panczner, curator of earth science at the time, and I planned a month's trip south of the border. Just before we left, Bill heard a large selenite cave had been encountered during mining at the Buena Tierra Mine in Santa Eulalia, so we headed that way. Sure enough, after some negotiating with the mine superintendent, we were able to get into that cave, the first Americans to do so. And what a cave! It had diverging selenite crystal sprays 15 feet across and individual crystals up to 7 feet in length. I know because we went back with a tape measure to document that place. The cave extended over 100 meters and was about 20 meters wide. That was some sight.

I never thought I would ever see anything like that again. I was wrong! Years later, while I was on the committee that puts on the annual show in Tucson each year, we had an inquiry from a fellow who wanted a booth at the show. He sent pictures of what he had been doing, pictures that included images of gypsum crystals he said were up to 50 feet long! It so happened I was show chairman, so I had the enviable task of inviting the fellow to be a dealer and at the same time telling him I was a magazine editor and would dearly love to visit that cave if that were possible! It was and I did! You know the rest of that story, as the pictures of these giant crystals have appeared on the pages of *Rock & Gem*.

To see the giant selenites, we went to Naica where the cave was. We made the trip into the underground in a truck, not like in Colombia, where your legs were the only transport. When we got to the cave, we found ourselves in a subsurface sauna where the temperature was 150 degrees and the humidity 100 percent. There we were, standing among mineral giants, crystals with a girth of maybe 4 feet and a length that extended to the ceiling of the cavity. It was scary, but really exciting. Now I can safely say I'll never see anything like that again. But hold on! Rumor has it that two more such caves have been encountered, so you never know!

Of course, my writing career got started by accident, as well. Back in the late 1950s, I was a subscriber—and still am—to *Rocks and Minerals* magazine, which was the creation of Peter Zodac, a major player in our hobby. At the time I was collecting fluorescent minerals, so I wrote to Peter asking why he did not have a monthly column on that aspect of our hobby. His answer was perfect. He said, "There is no fluorescent mineral column because you haven't written it yet!" I never did mind writing, thanks to having done tons of papers in high school and college and ending up doing my master's thesis on luminescent minerals. So I wrote a column, and the rest is, as they say, history!

The same is true of my association with *Rock & Gem*. I happened to attend the Federation Show in Anaheim, California, back in 1972. The location was perfect because I could enjoy the show and my wife could take the kids to Disneyland across the street.

While at the show, someone told me a fellow named Jim Miller wanted to see me. He was promoting a new magazine he was planning on publishing. We met and talked. I told him I could write maybe three or four articles a year. Little did I know that the "three or four" would evolve into 25 or 30 a year, plus this column. Obviously, Jim was better a judge of character than I was. As they say, accidents do happen!